FIRST LINES

OF

PHYSIOLOGY;

DESIGNED FOR

THE USE OF STUDENTS OF MEDICINE.

BY DANIEL OLIVER, M.D., LL.D., A.A.S.,

CORRESPONDING MEMBER OF THE ACADEMY OF SCIENCES AND FINE ARTS
OF PALERMO, AND PROFESSOR OF MATERIA MEDICA IN
THE MEDICAL COLLEGE OF OHIO.

1030

Multa esse constat in corpore, quorum vim rationemque perspicere
nemo nisi qui fecit, potest.—LACTANT. DE OPIFIC. DEI.

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PREFACE TO THE SECOND EDITION.

In offering a second edition of the First Lines of Physiology to the medical public, and especially to those who are preparing to enrol themselves among its numbers—for whose use the work was originally designed—the author thinks it proper briefly to state the principal alterations and improvements which have been made in the work.

1. No alteration has been made in the plan and general arrangement of the book, for none appeared on the whole preferable to that which was originally adopted. And here it may not be improper to remark, that the preliminary matter, constituting nearly one-fifth of the whole work, and comprising a description of the distinctive characters and of the elementary analysis of the organization,—anatomical, chemical, and physiological,—form, it is believed, an important and valuable part of the work, being fundamental to the whole subject of physiology, and being presented in a more systematic form than will usually be found in elementary treatises on this subject, except in the works of the German physiologists.

2. An addition of probably one-fourth has been made to the materials of the work, drawn from the latest and best sources which were accessible to the author. These will be found interspersed throughout the book, incorporated in various parts with the original matter; or embodied by themselves in considerable masses, and filling up *lacunæ* which existed in the first edition. Nearly every chapter of the work contains additions, more or less copious, of the first description, extended as far as con-

sistent with the prescribed limits of the work, or as was practicable without destroying the symmetry of its parts. The principal additions of this description will be found in the chapters on the Blood, Innervation, the Circulation, Digestion, Nutrition, Animal Heat, the Senses, especially touch, taste, and vision, Sleep, and Generation. Any one who will take the trouble to compare the corresponding chapters on these subjects, in the two editions, will perceive almost at a glance that those of the last have received copious, and it is hoped, important accessions of matter. Considerable masses of matter, constituting new sections, have also been added to several of the chapters, among which may be mentioned the section on the psychological functions of the brain; several sections on fœtal developement and physiology in the chapter on Generation; besides several shorter ones in the chapters on the Circulation, Digestion, Vision, Sleep, &c. On the whole, it is thought that the value of the work is materially increased by the copious accessions of matter which distinguish this edition from the first.

3. Few retrenchments have been made in this edition, for no considerable ones appeared to be called for. Probably a more critical or a less partial eye would have been more successful in the search after exceptionable passages. Among such the chapter on Animal Magnetism will probably be enumerated by many readers. I am aware that a large majority of those into whose hands this book may fall, probably regard animal magnetism as unworthy of serious attention, and as a fitter subject of ridicule than of sober consideration. Perhaps they are right, and I do not undertake to assert that they are not so; but I am not quite sure but it would be premature to assume this hypothesis for a certainty. My reasons for this hesitation are, that I find many intelligent men, after an examination of the subject, have been satisfied with the evidence in favour of its claims; men accustomed to the investigation of subjects of physical science, and at least as competent to judge correctly as those who have adopted the opposite opinion; and more so, I may add, than many of those who, without any experimental knowledge of the subject whatever, have held it up to ridicule and contempt. I repeat it, that men quite as competent to judge as any of us, and with vastly better opportunities of observation than most of us, as able

to weigh every fact, to appreciate every circumstance, to detect any imposture, and to reason soundly on the whole subject; men, it may be added, who can have no conceivable motive to deceive or to impose upon others; many such men, I say, have become convinced, and have avowed their conviction, of the reality of Animal Magnetism. "I repeat it," says Rostan, in writing on this subject, "what I am about to describe I have seen, and have seen frequently. I have not been satisfied to witness it in a single person, but have subjected numerous individuals to these investigations. I have taken as subjects of my researches individuals of various classes, and of both sexes,—persons many of whom were ignorant even of the name of magnetism, men of letters, students of medicine, epileptics, ladies of fashion, young females, &c. I have continued these inquiries for many years, and, with very few exceptions, I have always obtained results worthy of the greatest attention; and in nearly all these cases the phenomena were exactly of the same kind, or strikingly similar. Among these phenomena there were some of a very extraordinary character, which always appeared, others more rarely, and some but seldom." He afterwards proceeds to observe, that in these experiments it was *physically impossible* that there could be any collusion, or any communication whatever, between the persons on whom they were made. Now what are we to do with such testimony as this? And this is only a single specimen of what might be adduced. Are we to reject it with contempt, and to declare such men as the distinguished physician just cited, and many others who might be mentioned, to be fools or impostors, because they testify to facts which do not accord with a certain standard of truth or possibility which, in the plenitude of our knowledge and presumption, we have seen fit to set up, a standard derived from the little glimpses we have been able to catch of the secret operations of nature? How much of the intimate and essential nature of the nervous system do we know? How much of this *terra incognita* have we yet explored, which shall authorize us to say that nothing does or can lie beyond the reach of our own vision?

"But these stories about magnetism contradict experience, and therefore must be false!" The true expression of this fact is, that they do not fall within the sphere of common experience.

But can we say that there is not and cannot be a field of experience of more restricted limits, within which these facts may be as true as those which they appear to contradict are in the wide theatre of common observation? Is no concurrence nor combination of circumstances in physical or physiological nature possible, which may so modify the ordinary operation of the laws of nature, as to produce new and paradoxical results, and which, so long as the combination lasts, may constitute a new, though limited field of experience? And is this so certain, that rather than admit the contrary, we must reject testimony which on any other subject we should never have dreamed of questioning, and charge with wickedness or gross folly men who we have no reason to doubt are quite as capable and as honest as ourselves? Is it for us to dogmatize on this subject at a time when every year is revealing to us new wonders, and bringing to light new powers in the physical and organic worlds; and while it is enlarging the little circle of our knowledge, is still more disclosing to us the boundless extent of the unknown regions beyond? Is it for us, out of the fathomless depths of our own ignorance, to issue ordinances to nature, and to say how far her power extends and where it terminates? Let us listen to the words of a consummate judge of human nature, and consider for a moment how well they apply to ourselves in this matter. "But God be thanked," says Sir William Temple, in speaking of man, "his pride is greater than his ignorance, and what he wants in knowledge he supplies by sufficiency. When he has looked about him as far as he can, he concludes there is no more to be seen; when he is at the end of his line he is at the bottom of the ocean; when he has shot his best, he is sure none ever did or ever can shoot better or beyond it. *His own reason he holds to be the certain measure of truth, and his own knowledge, of what is possible in nature.*"

Considerations such as these, as well as personal observation, have had their weight with many persons who have taken no part in the discussions and controversies to which this subject has led. Many individuals of fair and honest minds, and some of them of high intelligence, have, to my own knowledge, been impressed with the reality and truth of this matter, but have been

backward to avow their conviction, because unwilling to incur the ridicule of their friends.

In some parts of Europe, this subject, as is well known, has obtained a strong foothold among scientific men. A distinguished foreigner from one of the most learned countries in Europe, a few years since, in reply to a question of the author, who asked him what was thought of animal magnetism at that time in Europe, used the following words: "Sir, there is no doubt whatever of its reality; but it is a dangerous power, and the exercise of it ought to be forbidden except under the restrictions of law."

It ought not to be forgotten, that the two most eminent philosophers of the age have treated the pretensions of animal magnetism with respect, and have even admitted at least the great probability that they have a real foundation in the nature or properties of the nervous system. When I consider the sober and cautious language of science on this subject, coming from the lips of philosophers of vast abilities, trained to habits of the severest investigation, and whose genius was successfully employed for a long series of years in unfolding the deepest mysteries of physical nature and of organization, I confess that the scoffs and sneers of ignorant or half-informed presumption are apt, by some hidden affinity of thought, to bring to my mind a certain sound which is described in the expressive language of Scripture as "the crackling of thorns under a pot." The discovery of the invisible thread of thought which leads to so singular a result, I would propose as a problem to the metaphysician.

The disciples of the school of the infinitesimal medicine I would remind, that the great founder of their system—"that fine old man," as I think Mr. Coleridge calls him—declares that none but fools or madmen can entertain a doubt of the curative powers of animal magnetism.

The followers of Gall and Spurzheim should not forget that zoo-magnetism and craniology sprung from the same soil; and that if the latter has expatriated itself among the mists of Caledonia, and taken another name, and has long since been forgotten in the land of its nativity, while the former still clings to

its native soil, they are still countrymen, and ought not to meet as strangers in a foreign land.

The philosophers of the supersensual school also should be reminded, that magnetism and transcendentalism have the same fatherland—the land of dreams and of mighty shadows, the land of the Hartz and the Brocken. The idolaters of nature will be slow to admit, that, whatever may transcend sense, any thing can transcend *her* power; though they will not deny that whether she speaks through matter either lifeless or animated, or from the lips of her own inspired hierophants, she sometimes utters oracles which are hard to be understood.

The reader will now understand why I nave not expunged the chapter on Animal Magnetism. I am no advocate for its pretensions; but I have so much respect for many of those who are or have been, that I wish to have it rescued from the hungry clutches of mountebanks and impostors, and placed under the protection of science, until its claims shall have received a thorough investigation.

In conclusion, I would only remark, that the book, in the main, is printed with great correctness; and that the errors or awkward expressions which may occasionally offend the reader's eye, will find a ready apology in the fact that the author's residence and the press are more than three hundred miles apart.

Boston, August 31st, 1840.

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FIRST LINES OF PHYSIOLOGY.

CHAPTER I.

DEFINITION.

Physiology is the science of life, or of the phenomena of living bodies; or it may be defined the science of organization; this term being used to express the living or active organization, and not being separable from the idea of life.

In contemplating the vast number of bodies which present themselves to our notice, we perceive that they may all be referred to two great classes, viz: the organic, and the inorganic; distinguished from each other by certain striking properties, and each embracing an immense number of subdivisions, or subordinate classes. In each of these two great departments of nature, we observe two objects or elements essential to the class of beings we are considering; one, *a corporeal mass;* the other, *certain general properties* belonging to it; or, a *material* and a *dynamic* element; and these two are inseparably blended together, or only separable by an act of thought. We no where find matter divested of physical properties, and it is only by mental abstraction that we can conceive of it as existing without them. For any thing we know, the property of attraction may be as essential to matter, as the corporeal mass which it presents to our senses. Attraction or gravitation, as isolated from matter, we know is nothing but an abstraction of our minds, and probably a corporeal mass isolated from the dynamic element of matter, that is, from its physical or chemical properties, is no less so.

The same is true of organized matter. It consists of two elements, a corporeal mass, and certain properties inseparably blended together. These properties, which in their aggregate we term *life*, we can separate in thought from the sensible mass, with which they are united, but they cannot be separated in reality from it. When we speak of *life* or *vital properties*, we

speak of mere mental abstractions, and we should never forget that this is the case, or we may be led into errors and absurdities in reasoning on the subject.

It may perhaps be supposed that, though life cannot exist without organization, yet the latter may exist separate from life, because we find by experience that all the external and sensible characters of organization remain some time after the extinction of life. Yet, beyond all doubt, death is always accompanied with some essential change in the organization, though it may not be possible for us, in all cases, to determine what this is. In most instances, the lesions of the organization which occasion death are obvious on dissection; and that they are not so in all, is probably owing to the fact, that science has never yet been able to penetrate into, and unravel the deeper mysteries of the organization, which constitute the immediate and essential condition of life.

The powers or forces which are connected with inorganic matter are of two kinds, mechanical and chemical; and all matter, without exception, so far as our knowledge of it extends, is subject to the influence of these forces. The changes which take place in the physical world, and the motions and transformations of lifeless matter, which constitute these changes, are the results of the operation of these forces.

In addition to these two, organized matter is endued with another kind of force, which may be termed *organic*, or *vital*, and which is of a higher order than the two former. It exists in connexion with the mechanical and chemical forces, for wherever it is found, they are present likewise. It cannot exist without them, though they may exist without it. But wherever the organic force exists, it modifies, in a greater or less degree, the mere physical forces of matter, and sometimes appears almost to subvert them; but, as soon as the organic power has ceased to operate, the two former immediately resume their empire, and soon bring back the organized mass within the domain of inorganic nature.

CHAPTER II.

COMPARISON BETWEEN ORGANIC AND INORGANIC MATTER.

A STRIKING difference exists between the structure and general properties of organic and inorganic matter. The structure or material composition of organized bodies is so peculiar and

specific, as to form a remarkable contrast with that of inorganic matter. Their other characteristics are no less peculiar and distinguishing. The most important differences between these two classes of substances, will be briefly noticed.

1. An organized body always possesses a certain determinate form, peculiar to the species to which it belongs. Every species has its own type, and this is so peculiar, that the systematic place of every plant and every animal in existence, might be determined by the manner in which it occupies space, or, in other words, by its external shape. Mineral substances, on the contrary, never possess a fixed and invariable form, though in a state of crystallization, they frequently present forms of great regularity.

2. All organized bodies, plants as well as animals, are distinguished by rounded forms, which approach the spherical, oval, or cylindrical, and sometimes are branching and articulated. They scarcely ever present straight lines, or plane surfaces, or sharp angles, or ridges, but are almost always bounded by curved or undulating lines, and by concave or convex surfaces. The forms of mineral substances, on the contrary, are bounded by plane surfaces, and straight lines, irregularly broken by sharp angles.

3. The volume of organized bodies is no less determined than their form. Every species of animal and vegetable, has its own proper size, to which, with accidental exceptions, every full grown individual belonging to it conforms. But there are no fixed limits to the volume of mineral substances. They may be either great or small, according to the quantity of matter they contain, yet be absolutely identical in their nature or properties. The smallest fragment of a mineral substance has all the properties of the mass from which it was taken.

4. Upon examining organized bodies with a microscope, they are found to contain minute particles of matter of a globular or oval, and sometimes flattened shape. The fluid, as well as the solid parts, both of animals and plants, abound in these minute globules. Some of the lowest classes of the animal world, as the infusory *animalcula*, and the *polypus*, as well as the most simple of the vegetable, *e. g.;* the *confervæ*, the *byssus*, &c. are composed of them. In most of the animal fluids also, as the blood, chyle, saliva, pancreatic fluid, the milk, the spermatic fluid, and the fat, globules have been discovered. They have also been observed in the peculiar juices of vegetables, particularly in those of the lactescent plants. They are found also in the cells of plants, and in the solid tissues of animals, as the cellular, mucous, and serous; in the brain, nerves, mucsles, tendons, and glands.

These globules, to which there is nothing analogous in mine-

rals, are considered by some physiologists as the elementary forms of organized bodies, as the ultimate organic molecules from which, disposed in various modes, the different tissues of animal bodies result. Arranged in lines, they form the fibrous tissues of the nerves, muscles, and tendons. Extended in the form of sheets, they compose the various membranes, the serous, synovial, and mucous, and the coats of the vessels. United in masses, they form the solid substance of the glands, as the liver, pancreas, kidneys, salivary glands, &c.

5. The internal structure of organized bodies, presents another very striking characteristic, which distinguishes them from common matter. Mineral substances are formed of homogeneous parts, which are perfectly similar in their physical and chemical properties; while organic bodies consist of various parts, which differ in their forms, properties, and functions. A mineral substance may exist either in a solid, liquid, or gaseous form; but it never presents a combination of these forms. It is either wholly solid, wholly liquid, or wholly gaseous. Whereas organic matter always presents a combination of solid and fluid parts. Organized bodies always consist of vascular or porous matter, with fluids contained in its vessels or interstices; and this composition is indispensable to the actions of living matter; for these result from the mutual influence of the fluids and solids upon each other. The various parts of which organized bodies consist, perform different functions in the economy of the individual; all of which however concur, each, in a peculiar manner, to the welfare and preservation of the whole. Every organized body is a *system* of organs, and can only exist by the association of these organs; each of these being absolutely essential to the existence of all the others. Whereas mineral bodies present no diversity of structure, and no reciprocal relations of different organs; and the parts into which they may be divided, can exist separately from their associates as well as when aggregated together by physical cohesion.

6. These two great classes of bodies differ also in their chemical composition. A mineral may consist of a single element, or may form a simple body, as diamond, sulphur, &c.; or, it may be composed of a great number of different elements, held together by chemical affinity, or by cohesive attraction. But organized bodies never consist of less than three elements; and animal substances contain at least four, viz. oxygen, carbon, hydrogen, and azote. Carbon may be considered as the characteristic element of one class of organized bodies, viz. vegetables; and azote of the other, or animal substances.

Further; a mineral has a fixed chemical composition, which undergoes scarcely any change under ordinary circumstances; while organized bodies are subject to incessant changes in their

composition, in consequence of certain internal motions, which are essentially connected with the presence of life, and which are accompanied with a constant waste and replacement of the matter of which these bodies are composed.

But another striking peculiarity in the chemistry of organic bodies is, that they consist of two kinds of elements; one, which may be termed *chemical*, such as exist in mineral bodies, as oxygen, carbon, hydrogen, and azote; and another, which may be called *organic*, because they are the product exclusively of the *organic* or vital forces, and are never found in inorganic matter; such as *albumen, gelatin, fibrin*, &c. It is owing to the fact that these last named elements are produced, not by the general powers of matter, but by the peculiar forces of organic life, that it is impossible for us to decompose, and to *reform* organic, as we can inorganic substances. It is only the *general* forces of matter of which we can avail ourselves in our experiments upon bodies. These will enable us to reduce to their ultimate elements all kinds of matter, both organic and inorganic. But they will not enable us to recombine these elements in those arrangements which constitute the organic elements; because this requires the agency of a new species of force, which is wholly out of the sphere of our control. It is not in our power to create a single particle of vegetable or animal matter; and our analyses of these substances are in fact nothing else than a destruction, more or less complete, of their organization.

Another important difference in the chemical composition of organic and inorganic bodies, relates to the mode in which the elements which enter into their composition are combined together. In organic substances the chemical composition is much more complex than in minerals, and from the same cause, less intimate and fixed. In mineral substances the combinations are for the most part binary, or their constituent elements are united by *twos*, and their affinities are completely saturated; so that these substances are comparatively fixed in their composition, and have but little tendency to change. However numerous the elements of inorganic substances may be, we always find them forming binary, or double or triple binary compounds. Water, the earths, the oxides and chlorides of metals, the acids, and many other substances, furnish examples of simple binary combinations. The carbonates of lime and of the alkalies, the earthy, alkaline, and metallic salts, glass, &c., are examples of double binary compounds. Solutions of saline substances in water, or the same substances in a state of crystallization containing water, afford examples of triple binary compounds.

It is difficult to form ternary compounds, on account of this strong tendency of the elements of matter to unite by *twos*. Let us take, for example, water, which is an inorganic fluid, com-

posed of two elements, oxygen and hydrogen, and we shall find that there are very few simple substances which it will dissolve. It will not combine with sulphur, carbon, phosphorus, nor with the metals; and but very sparingly with the simple gases. But it will readily dissolve all these substances in some state of combination with other elements. Thus, carbonic, sulphuric, and phosphoric acids, readily combine with water. Sulphuretted and phosphuretted hydrogen are also absorbed by water, though in very different proportions. The metallic salts, and the alkalies are soluble in water. What is true of water, is true also of other binary compounds; they refuse to unite, or they unite with difficulty, with simple substances; whereas simple bodies, as oxygen, chlorine, &c., combine with avidity with other simple substances, but not with bodies composed of two elements, except in certain special cases, or under peculiar circumstances. If we attempt to form a ternary compound, by uniting a simple body to a substance composed of two elements, the result is, either that no chemical action takes place between them, or, that the simple body exerts so strong an affinity for one of the elements of the compound, as to decompose it. If we add together any number of bodies, having affinities for one another, they never unite into one complex body, but always arrange themselves in binary compounds.

Oxygen, *e. g.*, is one of the elements of organic matter; but it never exists in it in sufficient proportion to saturate the combustible elements, carbon and hydrogen, with which it forms ternary compounds. Hence all organic matter is combustible. It burns when ignited in contact with the air, and then absorbs all the oxygen necessary to saturate its hydrogen and carbon.* In the ternary and other more complex combinations of organic matter in which the combining elements are held together by a feeble affinity, there is a constant tendency to separate and assume a binary arrangement, in which the affinities are more energetic, and more perfectly saturated. Thus, the ternary combinations of oxygen, carbon, and hydrogen, are resolved by spontaneous decomposition into the binary compounds, carbonic acid and water. If azote is one of the combining elements, as is the case with animal substances, it separates from the oxygen and carbon and unites with the hydrogen, for which it possesses a strong affinity, and forms ammonia, which is one of the characteristic results of animal decomposition.

From this tendency of the elements of animal and vegetable substances, to pass into binary combinations, arises the facility with which they are decomposed. The nice equilibrium, in which their elements are held in these complex combinations,

* Tiedemann.

can no longer be maintained after the vital forces, which formed them, have ceased to act. To adopt a familiar illustration, we may say, that the company breaks up, and each individual joins the friend for whom he has the strongest attachment.

Though the composition of organized bodies is much more complex than that of inorganic, yet the number of elements actually employed in the formation of them, is much less than that of those which exist in the latter. Vegetable matter is composed principally of three elements, viz. carbon, hydrogen, and oxygen; and animal matter of four, containing, in addition to the three former, another element, azote, from which it derives its principal chemical peculiarity. Besides these four, which are the essential elements of organic matter, it contains several others, but in very inconsiderable quantities, making in the whole about nineteen, which is little more than one-third of the whole number of elementary substances which have as yet been discovered by chemical researches.

It appears, then, that the structure of organized bodies presents the following characteristic features, viz. that they possess a determinate form and volume; are composed of particles of matter of a spherical shape; and possess a peculiar chemical composition, consisting, in almost all cases, of *three* or *four* ultimate elements, which are always the same, viz. oxygen, hydrogen, carbon, and azote; that these are combined together into ternary, or quaternary compounds, not by the operation of chemical forces alone, but by these modified by a new species of force, the organic, or vital powers; and they are formed into certain organic elements, which the common powers of matter are wholly unable to form, and which, on the contrary, they are constantly endeavouring to subvert; that organic bodies consist of solid and fluid parts; that the solid parts are not compact and homogeneous, but possess a fibrous and vascular, or areolar structure, in which the fluid parts are contained; and, lastly, that an organized body consists of an assemblage of organs, differing in their form, size, structure, and actions, but all mutually dependent on one another, and conspiring to produce the same result, the preservation and welfare of the individual.

7. The general properties by which organized bodies are distinguished from inorganic matter, are next to be considered. It has already been observed, that organized substances are not immediately subjected to the laws of chemical affinity, but that they are endued with a new species of force, by which these laws are modified, and which may be termed organic power. In consequence of this peculiar property, organic substances react against the physical and chemical influences of the external world in a peculiar mode, the intimate nature of which we are unable to discover, while its results are evident and extremely

curious. There is a perpetual conflict between organic and chemical power. The physical and chemical forces of nature unite in their endeavours to reduce under the general laws of matter these isolated masses, which have been wrested from them by a foreign power, which has superseded their own authority, and which is extending its conquests in every part of their empire. In this struggle the general powers of matter are, in every instance, sooner or later invariably successful. These forces are inherent in every form of matter, unwearied in their exercise, indestructible and inexhaustible; while the organic forces, are by their own nature limited in duration, exist only in connexion with particular forms of matter, isolated from the general mass, and maintained in a forced state of composition by the energy of these very powers, in opposition to the general laws of matter.

But, if organic power is, in every instance, sooner or later overcome and destroyed by the general powers of matter, it is constantly starting up and renewing the conflict elsewhere, and is successful for a time, though in the end always overcome by the steady opposition of these powers. So long as an organized body is animated with organic power, so long it resists the chemical influences to which it is exposed. Even when its organic power is weakened by disease or natural decay, the chemical affinities of its elements are restrained within very narrow limits; and it is only on the invasion, or near approach, of death in particular parts, or in the whole system, that the chemical forces begin to be developed, in the phenomena of incipient vegetable or animal decomposition. The conflict between chemical and organic power consists in the attraction which the elements of physical nature exert towards those of living matter, and which is resisted by the vital affinities between the elements of the latter; and, on the other hand, in the vital attraction of living matter towards certain elements of inorganic nature, an attraction which is counteracted by the chemical affinities which belong to the latter. But the seeds of discord exist also in the organic elements themselves. For both classes of powers, chemical and vital, exist in these elements, giving them different tendencies to combination, and of course mutually limiting each other. In fact, these two classes of powers, the physical and organic, may be more properly considered as mutually limiting, than as hostile powers. Each is restrained and kept in check by the other.

This power of reacting against and neutralizing the mechanical and chemical forces of matter, is exemplified in the faculty, possessed by animal bodies, of preserving a certain regular and invariable temperature amid very great changes of temperature of the medium in which they live; in the power of elaborating out of a vast variety of heterogeneous substances, viz. the dif-

ferent kinds of matter used as food, the same homogeneous products, viz. the chyle and blood; and in the power of moulding out of this fluid a great variety of curious tissues and organs, differing in their mechanical structure, in their composition and properties, and all compounded in opposition to the general laws of matter.

All organized beings, both vegetable and animal, are endued with the property of being affected by various external agents, of showing themselves sensible to the impressions which they thus receive, and of being excited by these to certain actions, which inorganic substances never exert. The phenomena of nutrition and growth, under the influence of external agents, imply the aptitude of being affected by the impressions received from them. Animals of all classes are excitable, their nutrition, and consequently the preservation of their lives, being effected under the influence of external agents, and their voluntary motions being frequently excited by various impressions from without. The egg and the seed are capable of entering upon a series of internal movements and developements, under the influence of warmth, moisture, and atmospheric air.

The irritating effects of many physical agents on living matter are the result of its endeavour to maintain its own integrity, and to assimilate to its own nature the agents which act upon it; and the nature of this reaction or excitement will depend on the properties of the agent, as well as on the powers of the living body. A cutting instrument is resisted by the living solid by the force of the vital affinity of the latter. Destroy the life of the part and the resistance is lessened; a fact which proves that the mechanical power of the instrument is limited by the vital properties of the organization.

Here the effect is confined to the effort of the living substance to maintain its own integrity. But if the effort be unsuccessful, and the vital resistance be not sufficient to overcome the mechanical power of the instrument, a new effort, of a different kind, consisting in a series of vital actions of a peculiar character, is made to repair the injury.

The spasm of a muscle occasioned by pricking it, is, perhaps, another example of an effort of living matter to resist physical injury, by condensing itself.

In these cases, no time is allowed for an effort at assimilation to be made on the part of the organized body. But if a foreign substance, soluble in the animal fluids, as a piece of iron, be left in the flesh, the assimilating power is then exerted, and the metal, if not discharged by suppuration, is corroded and absorbed into the blood. In like manner, knives, purposely swallowed, have been dissolved or digested in the stomach or bowels.

Chemical agents, in like manner, as heat, acids, and alkalies,

are resisted or limited in their action by vitality. Foreign substances existing in the blood are so masked that it is frequently impossible to detect their presence. It is evident, from these examples, that living bodies must be endued with various powers of resistance to injury; for as different agents attack living matter in different modes, the resistance of the organization must be varied in order to overcome them.

Besides the physical and chemical agents which may act injuriously upon the organization, there is a third and most important class of noxious agents, which act physiologically, and which are met by a different kind of resistance on the part of the organization. These are various poisons, especially the organic, and the *causes of disease*, the destructive influence of which is resisted, and very frequently with success, by the vital powers of the organization.

These conservative powers of the organization, are collectively termed the *vis medicatrix naturæ*, a property which it seems impossible, without the grossest absurdity, to deny to living matter.

All the instances just mentioned of resistance of the organization to mechanical, chemical, and physiological agents, of a noxious kind, are examples and illustrations of the same power of self-preservation. The same property is the basis of nutrition.

This property of being determined to certain movements or manifestations of force, under the influence of certain exciting causes or impressions from without, is supposed, by some physiologists, not to be limited to matter already organized and endued with vitality, but to be inherent in organic matter, which is still amorphous and devoid of life. This opinion is founded on what is called spontaneous generation, a process in which certain organic substances, as albumen, fibrin, gelatin, starch, gluten, gum, &c. spontaneously assume, under the influence of certain external circumstances, some of the lowest forms of animal and vegetable life.

9. Another distinctive property of organized bodies is, that their growth and increase proceed from within, while inorganic matter increases by external accretion. The surface to which the new particles of matter are applied, is *internal* in organic, but *external* in inorganic matter. Organized bodies grow by a series of internal developements; inorganic increase by the addition of matter applied externally to them. With the nutrition of organized bodies, which is accomplished by the continual intussusception of new matter, is connected an antagonist process of organic decomposition, in which the worn out elements are removed and discharged; so that a perpetual round of composition and decomposition is going on in all organized bodies.

10. Further, organized substances possess the power of producing beings similar to themselves, or, the faculty of generation.

This is a remarkable and exclusive prerogative of organized bodies, unless we admit, with some physiologists, that matter in certain forms and under particular circumstances, has the property of organizing itself into some of the lower forms of animal or vegetable life.

11. Organized bodies possess the power of being affected with, and of recovering from disease.

12. Organized substances have a determinate duration or period, beyond which it is impossible to prolong their existence. No power short of creative energy can prolong this duration beyond the period appointed by the laws of its own being. Its existence consists of a series of internal developements, each of which is the natural result of that which immediately preceded; and in a certain time the series, which in every species is unalterably determined by the laws of its being, is exhausted, and it then ceases to exist. Originating in a minute portion of matter derived from a being similar to itself, when placed in certain circumstances, it immediately commences a series of internal evolutions by which it gradually enlarges in magnitude; and its interior structure is more fully unfolded. A great variety of distinct parts, which were only imperfectly sketched out, or existed merely in a germinal state, are now gradually unfolded; and this process of internal developement goes on without interruption, until the organic mass reaches a certain magnitude, and acquires a certain form, which denote the zenith of its existence. This form and volume once attained, a certain period of time is consumed in consolidating its growth, and ripening its powers; after which a process of organic decay commences, and the individual, having fulfilled the object of its existence, is, by the inevitable laws of its own nature, conducted back, by a different route, to the world of physical nature from which it sprung. Its material elements are returned to the great magazine of nature, from which they were borrowed; its peculiar powers and properties are decomposed and lost among the mass of dynamic principles; and while its organs and its powers are resolved into numerous primitive elements, its individuality perishes, and its unity, both of matter and of power, is lost by diffusion in the vast ocean of nature.

The duration of life varies for each species of organized being, animal, as well as vegetable. Some insects live but a day, some plants but a year; while the life of man sometimes reaches to a century, and that of some trees to the term of many hundred, and even, it is supposed, several thousand, years. The destruction of organized beings is termed death, to which there is nothing analogous in the world of inorganic matter; and it is distinguished by two remarkable circumstances, viz. the abolition of the vital forces, or that internal energy which maintained the

organic structure; and the destruction of the body itself by a separation of its elements, effected by the exertion of their chemical affinities, which had been previously controlled and neutralized, as it were, by the vital powers.

CHAPTER III.

RELATION OF ORGANIZED BODIES TO HEAT, LIGHT, AND ELECTRICITY.

The relations of organized beings to the imponderable elements, Heat, Light, and Electricity, are of a peculiar kind, and worthy of particular notice.

All organized bodies have, to a certain extent, the power of regulating their own temperature; many of them possess the faculty of exhibiting electrical phenomena of a peculiar kind; and some of them the power of developing light, or of becoming luminous. All these powers are connected with the presence of life in organized beings. They cease with the extinction of the living principle, with the exception that organic matter, in certain stages, or under certain circumstances of decomposition, is phosphorescent, or becomes luminous in the dark.

Caloric. Living, or organized matter, possesses the power, to a certain extent, of regulating its own temperature. Living bodies develope heat from the interior towards the exterior by their own peculiar powers, instead of receiving it from surrounding objects. They do not *receive* but *produce* it; and they are capable of resisting, to a certain extent, the tendency of caloric to an equilibrium. A part of a living animal, exposed to a considerable degree of cold, instead of having its own temperature reduced, like an inorganic substance, frequently becomes warmer than before; the defect of *physical* heat being compensated by an excess of *organic*. It has been conjectured, that as these two kinds of heat are derived from such different sources, are connected with such different forms of matter, and are subject to such dissimilar laws, there may be some essential difference in their nature and properties. But in fact, caloric, however excited, when brought within the sphere of vitality, loses something of its chemical character and relations. Its affinities are modified; it combines, separates, accumulates, &c. after different laws; and its effects in many respects are widely different from those which it produces in lifeless or inorganic matter. In short,

there is no example of pure mechanical or chemical action in the living animal body. All is animalized; every thing bears the stamp and characters of life.

Organized beings differ much in their power of producing heat. As this faculty is connected with the living powers, and the exercise of it is one of the modes of their manifestations, it may be stated generally, that those which are the highest in the scale of developement, possess it in the greatest degree. Thus, plants have a lower temperature than animals; and the invertebrated animals a lower temperature than those which possess a bony skeleton: of the vertebrated animals, also, those which are lowest in the zoological scale, viz. fishes and reptiles, have an inferior temperature to that of birds and the *mammalia.* There are exceptions, however, to this general principle. Birds have a higher temperature than the mammiferous quadrupeds, though they stand lower in the scale of organization. Some of the mammalia, also, have a higher temperature than man. Many insects have a much higher temperature than would correspond with their position in the zoological scale. Those exceptions, as we shall see hereafter, admit of an explanation on other principles; particularly that the degree of organic heat in animals, depends on the degree of developement of the respiratory organs—those animals whose respiratory system is most complicated and perfect, possessing the greatest degree of animal heat. This principle, however, requires some qualifications. Animal heat is greatest, not absolutely in those animals in which the organs of respiration alone are highly developed, but in those which, besides, possess a highly developed nervous system, as in the case with birds when compared with insects.

The human race and the mammalia, however, do not possess so high a temperature as birds, though they have much more highly developed nervous systems; from which it is inferred, that animal heat, as far as it is connected with the nervous system, does not depend upon the degree of developement of this, absolutely, but only so far as this system is appropriated to the organic or nutritive functions, and its activity is not absorbed in those higher functions of the nervous system, in which the mammiferous quadrupeds, and in a much higher degree, man, surpass the feathered tribe.*

Organized bodies, also, have the power of resisting the heating influence of very high temperature, or of maintaining their own at nearly the same standard, under the two opposite circumstances of a higher and a lower temperature of the surrounding medium. When exposed to a degree of heat superior to the standard of their own temperature, the developement of organic heat from within is immediately checked, and the excess of

* Berthold.

caloric applied to the surface excites the exhaling vessels of the skin to a copious secretion of perspirable fluid, which absorbs the excess of caloric, and flies off with it in the state of vapour. The developement of organic heat is checked, under these circumstances, because an excess of external temperature depresses and weakens those functions, by the activity of which caloric is generated in the system. Thus, the nervous power is debilitated by extreme heat; respiration becomes slower and less perfect; digestion, nutrition, secretion, and in short, all the processes connected with the nutrition of the system, and carried on in the capillary vessels, where the evolution of animal heat takes place, are more or less enfeebled. Under opposite circumstances, that is, when the surrounding temperature is not sufficiently high, a more active developement of caloric takes place from within. All the operations of life are performed with increased energy, as respiration, the action of the nervous system, digestion, assimilation, and the secretion; and with these, calorification.

Plants possess the power of regulating their own temperature in a far less degree than animals. Indeed, some naturalists do not admit that they possess such a power at all. Certain plants, however, especially several species of the *arum*, as the *arum italicum*, the *arum cordifolium* and *arum esculentum*, develope a high degree of temperature at the period of infloresence. Hubert found that the heat of the flowers of the *arum cordifolium* rose to 45° Réaumur when the temperature of the air was only 21° R. The germination of seeds, also, is accompanied with an evolution of heat, a fact which is exemplified in the process of malting.

Electricity. There is also an organic electricity, as there is an organic heat. Living beings are idioelectric, i. e., capable of developing electricity, and of exhibiting electrical phenomena by the exertion of their vital powers. Many facts have been observed, by different physiologists, tending to establish the existence of a vital fluid, bearing a very close analogy to physical electricity and galvanism. Beclard observed that needles, plunged into the middle of a nerve, acquired magnetic properties. Beraudi pricked the crural nerve of a rabbit with two steel needles, isolated at their free extremities by a plate of *lac*, and found, at the expiration of fifteen minutes, that the needles had acquired the power of strongly attracting light substances, such as little fragments of paper; from which he inferred, that electricity is developed in the nervous system under the influence of vitality. Another physiologist, Weinhold, asserts that a spark may be obtained by approximating the two ends of a divided nerve towards each other.* All animals, probably, have more or less free electricity. The changes of form and combination, which are incessantly taking place in the matter of which their

* Lepelletier.

bodies is composed, must be constantly disturbing the electrical equilibrium, and releasing the electric fluid from its combined state. In the human race, electricity appears to be developed with much greater facility in some individuals than in others. Persons of an irritable temperament, it is said, have more free electricity than those of a dull phlegmatic habit. The use of alcohol is said to increase it. Some remarkable facts are on record, illustrating the developement of free electricity in the human body. It is related of a lady of Verona, that she used to terrify her maids by emitting bright sparks, accompanied by a crackling noise, when her body was rubbed or touched by a linen cloth. Another remarkable case, of recent occurrence, was that of a young lady of Orford, N. H., who had suffered a long time under ill health. The electrical phenomena first appeared during a vivid *Aurora Borealis.* When she was slightly insulated by a carpet, sparks passed between her and any conducting body which approached. These sparks were emitted by her fingers to the brass ball of a stove, at the distance of an inch and a half. The affection lasted several months.

But the most remarkable examples of electrical phenomena developed under the influence of vitality, are furnished by certain fishes, which are provided with electrical organs. In these fishes the electro-motive power, instead of being diffused throughout the solids and fluids of the animals, is centralized in a particular apparatus or set of organs, intimately connected with the nervous system. Of these fishes there are several kinds, as the *torpedo,* of which there are two species, the *torpedo marmorata,* and the *torpedo ocellata;* the *rhinobatus electricus,* the *tetrodon electricus,* the *gymnotus electricus,* the *trichurus electricus,* and the *silurus electricus.*

The electrical organs of the *torpedo* consist of an apparatus which may be compared to a battery of several hundred voltaic piles. This apparatus is formed of a great number of prisms, of from three to six sides, standing very close together, near the head and gills of the fish, and in a direction perpendicular to the surface. These prisms consist of membranous tubes, the sides of which are abundantly supplied with blood-vessels and nerves, and which are divided into cells by transverse membranous partitions. The cells are filled with an albuminous fluid. These organs receive three large nerves on each side, one derived from the fifth pair of cerebral nerves; the two others from the eighth, or the *par vagum.*

As the electrical apparatus of the *torpedo* resembles a battery of voltaic piles, that of the *gymnotus* may be compared to a battery of galvanic troughs. Two of these, a larger and a smaller, are found on each side of the spine, separated from each other by a long ligament, and by the superior muscles of the

vertebral column. The larger is found immediately under the skin, along the muscles of the back, and extends to the extremity of the long tail of the fish, where it terminates at a point. A smaller organ is found beneath the former, separated from it by a thick tendinous membrane, a layer of fat, and muscles. The structure of both is similar. They are composed of horizontal membranous plates, separated by an interval of about one-third of a line from one another, and crossed in a perpendicular direction by membranous partitions, in such a manner as to form a great number of cells, which are filled with a gelatinous fluid. These organs receive numerous branches of nerves from the spinal marrow, which ramify minutely on the walls of the cells. The extent of surface of these organs is very great. Lacepede calculated that the discharging surface of the electric organs in a *gymnotus* four feet long, is at least 123 square feet in extent.

The electrical apparatus of the *silurus electricus,* also resembles a galvanic trough. It is composed of a membrane situated immediately under the integuments on each side of the fish, arranged in the form of numerous rhomboidal cells, which extend from the head to the ventral fins. These small cells are filled with an albuminous fluid. The organ receives an abundance of nerves from a large branch of the *par vagum.*

The structure of these electrical organs, as well as the phenomena which they produce, point out a striking analogy between them and the voltaic battery. These organs exhibit, in their structure, a great resemblance to voltaic piles of the second class, inasmuch as they are composed of alternate strata of moist conductors of different kinds; i. e., membranous partitions, and a gelatinous or albuminous fluid. The electrical phenomena produced by them, however, are by no means to be accounted for by their structure alone, or the mechanical arrangement of the parts which form them giving rise to electrical excitement merely by contact. For it is found that the division of the nervous trunks which supply them, immediately destroys their power of giving electrical shocks, although their mechanical structure remains unaffected. Humboldt says, that when the *gymnotus* is cut asunder, the anterior part alone, from its connexion with the brain, continues to give shocks. From these facts we must infer, that the electrical discharge of the organs of these fishes is a vital act, which depends immediately on the influence of the nerves upon them; while the electrical organs themselves can only be considered as a necessary physical condition, or, as contributing, in a secondary manner, to the excitement and discharge, by contact. The discharges seem to be under the control of the animal's will.

The phenomena of these discharges point out a striking analogy between them and the effects of physical electricity.

The sensation produced by the shock, is very similar to that of an electric discharge, The shocks may also be communicated, not only by contact, but by the intervention of substances which are conductors of electricity. Moistened thread, or cloth, conducts the shock; but the same substances when dry are non-conductors. According to Humboldt and Gay Lussac, however, metallic substances will not convey the shock of the *torpedo*. The same is true of water, according to the same philosophers; for they experienced no shock on immersing their hands in the water near the fish. The effect was produced only on actual contact. In the *gymnotus electricus*, however, the propagation of electricity by intermediate substances, is much more evident. It sends its shock through the water to the hand placed near it, and small fishes, which are swimming by, are sometimes killed by its discharges at a considerable distance. Metallic substances, and even wood, placed in contact with the fish, will conduct the discharge; but sealing-wax and bees-wax are non-conductors. Several persons, forming a connected chain, may receive a shock, as from a common electrical machine, if the person who forms one extremity of the chain, is in immediate contact with the electrical organs of the fish, or is connected with them by means of a conductor of electricity. If the chain is broken by a non-conductor, the effect does not take place. In some experiments, sparks have been observed to accompany the discharges. To these facts it may be added, that Dr. Davy, by the discharge of a torpedo six inches long, converted eight needles into magnets. He also decomposed solutions by passing discharges through them by means of gold and platina wires.

Notwithstanding these and other facts, evidently of an electrical nature, there are others which point out a difference between physical electricity and that produced by the electrical organs of these animals. Many of the most common effects of electricity, it has been found impossible to produce by means of these organs. Thus, they do not influence, in the slightest degree, the most sensible electrometer. No attraction nor repulsion of light bodies is produced by them. It is impossible to charge a Leyden jar by means of them; and Davy was unable to effect the slightest decomposition of water, by repeated discharges of a *torpedo*.

The discharge of the electrical organs of these fishes is an act of the will. Unless the animal exerts a voluntary act, no discharge takes place. A strong and vigorous fish has sometimes been seized with both hands without giving a shock; while, at other times, the slightest contact has been sufficient to excite one. Humboldt is of opinion, that the *torpedo* has the power of sending his shock in whatever direction he pleases. My friend, Dr. Francis W. Cragin, of Surinam, informs me,

that the discharge of the *gymnotus electricus* is propagated in every direction, in the water. If the hand be plunged into any part of the tub in which one of these eels is contained, it will receive a shock, whenever the animal is irritated to make a discharge.

After giving a shock, electrical fishes have the power of speedily charging their battery again. But the frequent repetition of the discharges exhausts them, and their shocks become weaker, unless they have a period of repose to recruit their vigour.

The division or tying of the nerves which supply the electrical organs, destroys their power of giving shocks. The destruction of the brain of the animal produces the same effect; but the power of giving shocks survives, for some time, the excision of the heart.

There are, however, two electrical phenomena exhibited by animals, which are not of a vital character. One is the production of sparks by the friction of the fur of certain animals, particularly the cat, the rabbit, the dog, the horse, &c. Of the same nature are the sparks which are frequently observed on pulling off the stockings in cold dry weather, and on combing the hair. In these cases, electricity is excited merely by friction. The galvanic phenomena exhibited by living animal organs, under certain circumstances, are examples of the other. Electricity excited in these cases is not of a vital character, but is produced by the mutual contact of heterogeneous animal substances, as muscles and nerves, disposed in such a manner as to form a chain; precisely as it is by the contact of different metals with each other, or with moistened substances arranged in the same manner. The effects are still more striking, if the muscles and nerves, which form the animal chain, are armed with metallic coatings, which are made to communicate by means of a metallic wire. In these cases, electricity is excited by the contact of heterogeneous substances.

That electricity should be excited in living bodies, is what we should naturally expect from the fact, that most of the conditions which are necessary to the excitement of it in inorganic matter, exist in living substances; as, for example, the changes of form and composition which are constantly taking place in the vital processes of digestion, nutrition, respiration, secretion, the evaporation of liquids, &c. The living body is a laboratory, in which matter is undergoing incessant changes of form and aggregation; fluids are passing into solids, and solids into fluids, and fluids into gases or vapours; and in all these processes, heterogeneous substances, as fluids and solids, are brought into contact, and mutually act upon each other. These circumstances are precisely those, which, in inorganic matter, give rise to electri-

cal manifestations. Most of the operations in nature, in which two heterogeneous substances enter into mutual action, occasion a disturbance of the electrical equilibrium, and the production of electrical phenomena. And, according to Donné, there are electrical currents in living bodies, which are caused by the acid and the alkaline states of certain membranes or organs, representing the opposite poles of a galvanic pile.

Thus, the whole skin secretes an acid fluid; while the lining membrane of the whole digestive canal from the mouth to the anus, except the stomach, secretes an alkaline mucus. The saliva, the mucus of the œsophagus, and that which is secreted by the whole intestinal canal, is alkaline. The serous and synovial membranes also, in the healthy state, secrete an alkaline liquor, which in certain diseases is liable to become acid.

According to Donné, the skin, which is an acid membrane, and the internal alkaline membranes, represent the two poles of a pile, between which electrical currents are determined, the effects of which are appreciable by the galvanometer. For if one of the conductors of the instrument be placed in contact with the mucous membrane of the mouth, and the other with the skin, the magnetic needle deviates fifteen, twenty, or even thirty degrees, according to the delicacy of the instrument; and its direction indicates that the alkaline or mucous membrane takes *negative*, and the skin *positive*, electricity. Similar polarities, or opposite chemical states, exist between other organs, especially the stomach and liver, between which, according to Donné, there are powerful electrical currents. The chemical nature of the secretions may be changed by disease, the acid becoming alkaline, and *vice versâ;* and these changes, according to M. Donné, occasion modifications of the electrical currents which exist between different organs. Acidity is usually the result of inflammation, and the acid which is developed by inflammation is the *hydrochloric.*

In relation to the electrical state of individuals of the human race, under different circumstances, Pfaff and Ahrens, by experiments made with a gold-leaf electrometer, upon persons placed on an insulating stool, obtained the following results:

1. In a state of health, the electricity of the human body is generally positive.

2. Irritable men, of a sanguine temperament, have more free electricity than those of a dull, sluggish, phlegmatic habit.

3. In the evening, the quantity of free electricity is greater than at any other time of the day.

4. Spirituous drinks increase the quantity of electricity.

5. Women are more frequently in a negatively electrical state than men. Gardini observed this electrical condition in females at the period of menstruation, and during gestation.

6. In rheumatic diseases the electricity sinks to zero; and as the disease disappears, gradually rises and becomes apparent again.

Phosphorescence. Another example of the developement of the imponderable elements by organized matter, is furnished by the phosphorescence of many animals and plants. Inorganic substances exhibit this phenomenon under the following circumstances, viz.*

1. Some have the property of shining in the dark, after having been exposed to solar or other light for a certain time. This is the case with the diamond, calcareous spar, marble, strontian, and some other bodies; and in a less degree, with alabaster, saltpetre, muriate of ammonia, galena, &c. The phosphorescence takes place in all transparent media, and even in a vacuum, with a sensible evolution of heat.

2. Many substances shine in the dark, after having been exposed to a certain heat, as chalk, barytes, strontian, magnesia, rock crystal, quartz, topaz; the filings of many metals; as zinc, antimony, iron, silver, and gold. In these cases, heat appears to act by overcoming the affinity of these bodies for light, and setting this element free.

3. Friction, percussion, and compression, are accompanied with a disengagement of light in many substances, particularly in those which are rendered phosphorescent by insolation or exposure to heat. Certain fluids, as water and air, give out light when suddenly compressed.

4. The crystallization of salts, in the water in which they were dissolved, is sometimes accompanied with a disengagement of light. This has been particularly observed in the *sulphate of potash*, and the *fluate of soda.*

5. Intense chemical action is generally accompanied with an evolution of light.

6. Electrical phenomena frequently give rise to a disengagement of light. Some bodies are rendered luminous by the transmission of an electric shock through them; and the fluid itself frequently becomes visible, under the form of a vivid spark.

Many organic substances destitute of life, give out light under circumstances exactly similar. 1. Some after exposure to solar light, as flour, starch, gum arabic, feathers, horn, coral, snail shells, teeth, pearls, bones, &c. 2. Some after exposure to heat, as volatile and fixed oils, sugar, wood, &c. 3. Some by friction, as sugar, manna, resins, &c.: olive and essential oils, when shaken in a vacuum. 4. All organic bodies during their combustion. 5. Resinous substances when electrically excited by friction.

Many organic substances, also, are phosphorescent during the

* Tiedemann.

process of decomposition. Dead vegetable matter, particularly the wood of trees, and especially that of the roots, when decomposing under the influence of a moderate heat, and of moisture, and without being fully exposed to the atmosphere, is frequently phosphorescent. It is remarkable, that great heat and a freezing temperature, are both destructive of the phosphorescence. The light becomes stronger, but continues a shorter time, in condensed air. In oxygen gas, the phosphorescence is not increased in intensity, but continues a longer time. It ceases in a few hours in azote, hydrogen gas, and the phosphuretted hydrogen, but reappears on the admission of atmospheric air. It disappears in a few minutes in carbonic acid, sulphuretted hydrogen, chlorine, ammonia, and muriatic acid gas. It is speedily extinguished in fixed oils and alcohol, ether, lime-water, and diluted acids. It disappears instantly in sulphuric acid. In oxygen, it occasions a loss of the gas, and a production of carbonic acid. From these facts, Gmelin inferred, that during the decomposition of wood, there is sometimes formed an organic and very inflammable compound of carbon, hydrogen, and oxygen, which, like phosphorus, burns with an evolution of light at the ordinary temperature of the air. It is not improbable that phosphorus itself may be one of the ingredients of this compound, and contribute greatly to the effect.*

Dead *animal* matter, however, much more frequently exhibits the phenomena of phosphorescence than vegetable. Dead fish, particularly the marine molluscous fish, in the incipient stage of putrefaction, often exhibits it in a high degree. It usually begins a day or two after death, when the animal is exposed to the atmosphere, or to oxygen gas, moisture, and a moderate temperature. A freezing temperature, and the heat of boiling water, equally suspend it. The phosphorescence does not appear in a vacuum, in carbonic acid, hydrogen, or sulphuretted hydrogen gas. Lime-water, alcohol, ether, and strong solutions of alkalies, salts, and acids, destroy it. But it appears again when these solutions are diluted with a large quantity of water. On the surface of the fish, during its phosphorescence, a gelatinous fluid matter is observed, which is the source of the luminous appearance. It may be washed off with water, which dissolves it, and becomes luminous itself. The phosphorescence ceases as soon as the decomposing fish exhales a fetid odour. From these facts it seems probable that the phosphorescence of dead animal matter is occasioned by its decomposition, followed by the formation of a combustible compound, which probably contains phosphorus, and which burns slowly with the evolution of light, in atmospheric air, or oxygen gas, at a moderate temperature.†

* Tiedemann. † Ibid.

But light is frequently given out by organized bodies, under the influence of vitality. It is asserted by some philosophers, that the flowers of several plants emit luminous sparks after sunset, in clear warm summer evenings. Several of the cryptogamous plants are said to be phosphorescent. The appearance has been most frequently observed in those which grow in warm and humid situations, as in mines; particularly in a cryptogamous plant, called the *rhizomorpha.* The phosphorescence of this plant becomes more vivid in a temperature of 40° C. It does not give out light in a vacuum, nor in a gas which contains no oxygen. It shines brighter in oxygen gas than in atmospheric air, and consumes part of the oxygen, with the production of carbonic acid. The phenomenon ceases with the life of the plant. It seems to depend on the emanation of an inflammable vapour, which undergoes a slow combustion in atmospheric air, and oxygen gas. The *dictamnus albus* is said to diffuse around it, during warm summer evenings, an atmosphere which takes fire on the approach of a lamp, and burns with a brilliant flame.

A great number of animals, also, both aquatic and aerial, exhibit luminous phenomena. Most of the inferior classes of animals which inhabit the sea, as the *infusoria,* the *medusæ,* the *radiaria,* the *annelides,* many of the *crustacea,* the *mollusca,* and even some of the fishes, are phosphorescent. The luminous appearance of the ocean, which is frequently observed, particularly in the tropical climates, is derived from this source.

The marine animalcula, contained in a vessel filled with sea water, have been observed to be phosphorescent, whenever the water is agitated by shaking the vessel. Diluted sulphuric acid, poured into a vessel containing luminous animalcula, has been found to occasion a sudden brilliant light, which immediately afterwards disappeared. The phosphorescence of the medusæ has been observed to increase whenever the water containing them was warmed. In alcohol, also, their light became more vivid; but this fluid soon killed them, and their phosphorescence disappeared. The phosphorescence takes place during the motions of the animal, and is more vivid in proportion to their vivacity and energy.

The light emitted by some of the phosphorescent marine animals, is most vivid at the time of propagation; and it is asserted by some observers, that even earth-worms are phosphorescent at the period of their amours. A viscid matter exudes from some of the phosphorescent marine insects, which is also luminous, and which communicates a luminous appearance to the finger, and even to the mouth and saliva of those who eat them. The light disappears in a vacuum, but returns on the re-admission of the air. A moderate heat increases its vividness, but the heat of boiling water, or cold, equally destroys it. The phosphorescence

continues some time in oil. A dilute solution of muriate of soda, or of nitrate of potash, or the spirit of sal ammoniac, increases its brilliancy; while concentrated solutions, vinegar, wine, alcohol, sulphuric acid, and corrosive sublimate, speedily destroy it. It continues some time after death, but is extinguished at the commencement of putrefaction.

Among the animals which live in the air, the tribe of insects furnishes the greatest number of phosphorescent animals. The source of the light in insects, has its principal seat in the posterior rings of the abdomen. It seems to reside in a peculiar albuminous matter secreted by the animal, which is phosphorescent when exposed to a moderate heat, and to atmospheric air; but ceases to emit light when coagulated by alcohol, ether, corrosive sublimate, or concentrated mineral and vegetable acids, &c. The phosphorescence also disappears in the non-respirable gases, and in a vacuum, but returns on exposure to atmospheric air or oxygen gas.

The phosphorescence usually commences at dusk, and at an earlier period if the insects be put in a dark place. It seems to be under the control of the animal's will; for a sudden noise will sometimes instantly cause it to cease. Some naturalists attribute the phenomenon to the action of the nerves; others to the faculty possessed by insects of accelerating or retarding their respiration, with which they suppose the emission of light to be connected. It seems to be certain, that the motions of the insect increase the phosphorescence.

The phenomena of phosphorescence require a certain temperature of the air. At a certain degree of cold, the emission of light ceases, and, on the contrary, its vividness increases if the temperature of the air be elevated within certain limits. If one of these insects, when not emitting light, be plunged into warm water, the phosphorescence commences; and if the temperature of the water be raised, it increases until the heat reaches a certain point, at which the emission of light ceases. If living insects be plunged into water heated to a degree sufficient to kill them, they emit a very vivid light at the moment they perish.

The phosphorescence requires the presence either of atmospheric air or oxygen gas. If luminous insects be placed in the receiver of an air-pump, the light which they emit gradually becomes fainter in proportion as the air is exhausted. In oxygen gas their light becomes very brilliant, and still more so, if the gas be heated. The protoxide of azote produces a similar effect. Chlorine gas destroys them instantly. In hydrogen gas, carbonic acid, sulphuretted and carburetted hydrogen, and azote, which soon kill the insects, the phosphorescence speedily ceases. The emission of light continues some time in warm water, but

soon ceases in alcohol; and is instantly annihilated by the concentrated mineral acids.

An electric or galvanic current, in some instances, has been found to excite a brilliant phosphorescence in the insects exposed to it. Mechanical and chemical irritations, productive of pain to the insect, have also been found to produce the same effect.

Tiedemann supposes, that the phosphorescence of insects depends on a peculiar animal matter, secreted by certain organs. This matter probably contains phosphorus, or some other combustible substance, which combines with the oxygen of the air, or with that contained in the water, at a medium temperature, and thus gives rise to the disengagement of light. The secretion of this substance is an operation of life, and is influenced by various external agents, which exert an influence upon the vital actions of these insects. But the phosphorescence itself is not of a vital character; it depends entirely on the composition and qualities of the luminous matter, and sometimes continues for several days after the death of the animals.* The only example of vital phosphorescence in the human system is furnished by the eye. In this organ the retina becomes luminous by pressure. It is well known that when the eyeball is pressed outwardly by the end of the finger applied near the inner angle of the eye, a luminous circle will be seen opposite to the point of pressure. A feebler light is produced by pressing upon the outer angle of the eye. The effect may be produced even in total darkness; and hence it follows that the retina, when compressed, is capable of emitting light, in the total absence of external light. It is to be observed, however, that this *organic light* is visible only to the eye which produces it. The production and the perception of the light are identical phenomena.

CHAPTER IV.

COMPARISON OF ANIMALS AND VEGETABLES.

Organized beings are divided into two great classes, viz: animals and vegetables, distinguished from each other by certain characteristic features.

Vegetables are organized living bodies, destitute of feeling and consciousness, and of the power of locomotion. They draw their nourishment from without by absorption at their surface,

* Tiedemann.

or by means of roots. They are composed of a homogeneous substance, forming roundish oblong cells, in which the solid or fluid matter of the plant is contained, without presenting any other kind of tissue. They reproduce themselves by temporary organs, which always die before the plants themselves.

Animals are organized beings, endued with consciousness and feeling, and the power of locomotion. All animals, from the zoophyte to man, are provided with an internal cavity for the reception and elaboration of the food. They are also much more complex in their organization, presenting a great variety of tissues and organs. They contain a much larger proportion of fluid, and a much smaller proportion of solid parts, than vegetables. They are composed of a greater number of chemical elements, and always contain azote in addition to the principles which exist in vegetable bodies.

CHAPTER V.

DIVISION OF THE ANIMAL KINGDOM.

The animal kingdom presents an immense variety of species, which are arranged in various classes, and subordinate divisions. One of the most general divisions of the animal world, is into *vertebrated* and *invertebrated;* the former embracing those animals which are provided with an interior bony frame or skeleton; the latter comprehending all such as are destitute of it.

Again: the vertebrated animals are divided into two great sub-classes, the *warm* and the *cold-blooded* animals; the former including those which possess a temperature considerably higher than the medium in which they live; the latter those whose temperature exceeds but little that of the surrounding element. Further; the warm-blooded animals either produce living young, which they suckle, or hatch their young from eggs. The former, or viviparous warm-blooded animals, constitute a great and important division of the animal kingdom, under the name of the *mammalia;* the latter, or the oviparous warm-blooded animals, form the immense family of *birds.*

The cold-blooded vertebrated animals are also divided into two great sub-classes; one includes those which breathe by means of lungs, and comprehends the *reptiles,* forming the four orders, serpents, tortoises, frogs, and lizards; the second embraces the cold-blooded animals, which breathe, not by lungs, but by a different set of organs, called gills; these are the *fishes.*

The *invertebrated* animals constitute the inferior division of the animal kingdom, embracing insects, worms, the molluscous animals, zoophytes, and the infusory animalcula.

TABLE OF A CLASSIFICATION OF ANIMALS.

ANIMALS.	VERTEBRATED.	Warm-blooded.	Viviparous, and having breasts.	1. MAMMALIA.
			Oviparous.	2. BIRDS.
		Cold-blooded.	Breathing with lungs.	3. REPTILES.
			Do. with gills.	4. FISHES.
	INVERTEBRATED.	With articulated bodies.	Articulations, both of the extremities, and of the body; but chiefly of the former.	5. INSECTS, CRUSTACEA, ARACHNIDÆ.
			Numerous annular articulations of the body.	6. ANNULATA.
		Unarticulated bodies.	Body naked, covered with a slimy membrane, or inclosed in a calcareous shell. Breathing by gills or lungs, with sexes separate, or hermaphrodite. Blood, white. Head, not distinct from the body.	7. MOLLUSCA.
			Having a stellated or radiated disposition of the parts, both external and internal, and provided with organs of respiration.	8. RADIATED ANIMALS. *Sea-nettle, Star fish, Medusa, Holothuria, &c.*
			Without organs of respiration.	9. ZOOPHYTES. *Polypus, Coral, Infusory Animalcula.*

The human race belongs to the great class of the *mammalia*, i. e. of warm-blooded, viviparous animals. Some animals of this class approach so near to man in organization and external shape, that they have received the name of anthropomorphous animals. This is the case with the *simiæ*, or ape tribe. The points of difference, however, are so numerous, as to have led many naturalists to form the human into a distinct and separate class. Some of these distinguishing marks are the following, viz:

1. *The upright position.* That this is natural to man, is evident from the structure of his body, particularly the great size of his head, and the absence of the strong ligament of the neck, with which quadrupeds are provided for the support of their heads; the great comparative size of the lumbar region, the breadth of the pelvis, and of the os sacrum, evidently designed to support a great superincumbent weight; the bulk of the *glutæi* muscles, whose power is exerted in extending the pelvis on the thighs, and maintaining it in that state, in the erect position of the trunk. In the mammalia, even in the *simiæ*, the *glutæus maximus*, which in man is the largest muscle in the

body, is very small and inconsiderable. The extensors of the knee joint, also, are much stronger in man than in the *mammalia.* The effect of the action of these muscles, is to preserve an extended state of the limbs, which is essential to the upright position. The *gastrocnemii* muscles, are also much more highly developed in man. We find, accordingly, that no other animal has calves equal to those of man. These muscles are necessary to progression; for, by raising the heel, they elevate the whole body in the act of walking. The large size of the feet, forming an ample basis for the body to rest upon; the angle which the soles of the feet form with the axis of the body; the concave form of the sole and the greater prominence of the heel, designed to give attachments to the strong muscles of the calf, and to support the back of the foot, are further proofs that the perpendicular position is natural to man. In other mammiferous animals, the *os calcis* does not touch the ground. Many animals, as the dog and cat, do not even rest on the tarsus, but merely on their toes. But in man, the whole surface of the tarsus, metatarsus, and toes, rests on the ground. To these peculiarities of structure may be added the position of the eyes, and the shortness of the upper extremities, which evidently point out the erect position as natural to man.

2. *The free use of both hands.* This prerogative of man is evidently connected with the upright position. If two limbs are sufficient for the support and progression of an animal, the two others are left free for other uses. Man is the only *two*-handed animal. The *simiæ*, which approach the nearest to man, are strictly four-handed, or *quadrumanous* animals, and of course are neither bipeds nor quadrupeds. They have thumbs on their lower, as well as on their upper extremities; and their feet are instruments of prehension, as well as their hands. In man, the difference in structure between the hands and feet, evidently proves that they were not intended to perform the same functions. One is organized for support, the other for prehension.

3. *The prominence of the chin*, the perpendicular direction of the inferior incisor teeth, and the absence of the intermaxillary bone, are also characteristic marks of man. Another circumstance is, that in man the teeth are of the same length; whereas, in other animals the various kinds of teeth differ in length, and are separated by intervals from one another. In inferior animals, the canine teeth are much longer than their neighbours, and are separated from them by a considerable interval.

4. Man is physically defenceless. He is not provided by nature with weapons either for attack or defence. He remains in a helpless state after birth longer than any other animal, and is indebted to reason alone for his instruments of aggression or self-defence.

5. In man the facial angle is greater than in any other animal. In the best formed human head it amounts to between 80° and 90°. In the ape tribe, the facial angle is vastly inferior to that of the least favourable specimens of the human species. The largeness of this angle in man, depends on the great developement of the forehead and anterior part of the brain.

6. Man has the largest brain, in relation to the volume of the nerves. This position is generally true, but there are some exceptions to it.

7. The sexual instinct is equally active at all seasons, and is not an irresistible impulse, but is subjected to the dominion of reason.

8. Man is the only animal that sleeps on his back.

9. He is the only animal that laughs and weeps.

10. He is the only animal which possesses an articulate language, expressive of ideas or mental conceptions.

11. He is the only animal endued with reason, a moral sense, and a sentiment of religion.

12. He can adapt himself to greater varieties of climate, and is more widely diffused over the earth's surface than any other animal.

CHAPTER VI.

ANATOMICAL ANALYSIS, OR STRUCTURE OF THE HUMAN BODY.

The human system is a very complicated machine. It consists both of solids and fluids, or, of containing and contained parts. The fluids constitute much the larger portion of the whole, bearing to the solids the ratio of about 9 to 1, according to some physiologists; or of only 3 to 1, according to others. The first estimate is probably much the nearest the truth.

The solids are composed of the same chemical principles as the fluids, and are reducible by analysis to the same ultimate elements. This follows as a natural consequence from the fact, that the solids are formed out of the fluids, by new combinations of their particles, under the direction of vital or organic affinity. In the formation of the solids, the particles of matter are arranged in various modes. If we may believe some microscopical observers, the ultimate animal solid is a minute sphere or globule of matter of extreme minuteness, not exceeding in diameter the 8000th part of an inch. This is supposed to be the ultimate mechanical element of the animal organization, from which,

disposed in various modes, are formed a great variety of animal solids. These may be arranged in the order of their simplicity, into filaments, fibres, tissues, organs, apparatuses, and systems.*

A *filament* is composed of a series of the primitive molecules, arranged longitudinally or in a row. Several of these filaments united together in a bundle, form a *fibre*. In this manner are formed the muscular and nervous fibres. A *tissue* is composed of fibres disposed collaterally or in planes, so as to form an expansion or membrane; or, intersecting one another at various angles, in such a manner as to form spongy solids, with areolæ or interstices dispersed throughout them. The cellular, serous, and mucous tissues are thus formed. Different tissues, disposed in a certain manner, so as to form a distinct piece of animal mechanism, designed to perform a particular office, constitute an *organ*. Thus a muscle, a nerve, a bone, the stomach, the brain, &c., are organs. Some of the organs are extremely complicated in their structure, as the eye, the ear; the viscera contained in the great cavities, as the lungs, liver, intestines, &c.

Sometimes several organs are associated together for the purpose of accomplishing a common object. Such an assemblage is called an *apparatus*. Thus, the apparatus of digestion consists of the mouth, teeth, œsophagus, stomach, intestines, liver, pancreas, lacteals, &c.; all of which organs concur toward the same object, the assimilation of food.

The term *system* is applied to an assemblage of organs, which possess the same or a similar structure. Thus, the nervous system consists of a variety of organs which, however differing in figure, magnitude, and situation, agree together in possessing one common structure. The same is true of the muscular system, that of the bones, ligaments, vessels, &c.

The first step in organizing the animal frame out of the primitive molecule, is the formation of the filament, which may be regarded as the elementary animal solid. The next is the formation of the fibre, by the union of several filaments in a bundle. The fibres may be regarded as elementary, in relation to the tissues, which are all formed out of fibres.

Such is the common view. That of Raspail, founded on microscopical observation, is widely different, but extremely plausible and ingenious. The organic vesicle is composed, according to Raspail, of a combination of carbon, oxygen, and hydrogen, in variable proportions, or of carbon and water, represented by the symbol ($C+OH^2$), united with an earthy or volatile base. The vesicle thus organized becomes the germ and generating element of the organs. These vesicles contain within them the germs of others, possessed of the same structure

* Library of Useful Knowledge; Article, Physiology.

and aptitudes, and enclosing a third order of germs, and so on in an indefinite series. Organization, therefore, says Raspail, may be considered as a kind of vesicular crystallization, endued with the power of indefinite developement. This vesicular crystal has the power of imbibing gases or fluids in contact with it, and of converting them into organic fluids. At the moment of its formation, the organic molecule, according to Raspail, is an oily substance, resulting from the intimate union of hydrogen with six times its weight of carbon. In this state it possesses the power of imbibition, and if exposed to atmospheric air, it absorbs, eventually, oxygen enough to saturate its hydrogen, so that the molecule may then be represented by one portion of carbon and one of water. In this stage of its formation it takes the character of gum, assumes the spherical form when suspended in a fluid, and continues to absorb gases; and at the same time it acquires a tendency to combine with inorganic bases, especially earthy and alkaline substances, as lime, potash, soda, ammonia, and some others. In this state, says Raspail, the vesicle is an organ endued with life, and with the faculty of indefinite reproduction, by organizing, after its own type, the fluid contained in it.

Every organized being, in this view, is formed by vesicular evolution, and every organ may be considered as a vesicle in a certain stage of developement, or modified in a certain manner. Thus, a bone is a vesicle elongated or otherwise modified in its shape, and incrusted with calcareous salts; a muscle an elongated cell endued with the power of contraction; a gland is a cell connected by a hilum to the parietes of the cavity which contains it. The vessels are canals formed in the interstices of the cells, by the fluid imbibed by the external cell forcing itself a passage between contiguous cells by separating them from each other.

A filament, according to this view, is composed of an elongated imperforate vesicle. A tissue, like the adipose or cellular, is formed by successive orders of vesicles, produced by a series of internal developements; a structure which may be illustrated by the mechanical division of a small piece of solid animal fat, as mutton or beef tallow. It will be found, says Raspail, that such a mass is composed of an external vesicle, with strong membranous coats; that within it are contained smaller masses, easily separable from one another, and each invested by a vesicular membrane, with more delicate coats than those of the external one, and inclosing in its turn a certain number of still smaller masses, and so on successively until we arrive at the primitive vesicles, which contain the granules of fat. Each of these vesicles of an inferior order, is attached, by some point of its surface, to the internal face of the vesicle which contains it,

and is the result of the developement of the latter; and the whole mass may be easily conceived to arise in this manner from a single vesicle, by a series of internal developements.

CHAPTER VII.

FUNDAMENTAL TISSUES.

The solid part of the body is formed out of three fundamental tissues, the *cellular*, the *muscular*, and the *nervous*. All the solids of the body, however numerous, and however widely they may differ one from another, as the bones, ligaments, cartilages; the vessels, muscles, nerves, &c. may be analyzed, anatomically, into one or more of these three.

Of these tissues, the most generally diffused, and the simplest in structure, is the *cellular*. This tissue enters into the composition of every organ, and is the basis of the solid structure of the body. It forms, in fact, a kind of frame-work of the body, so that if every other kind of animal matter were removed, the cellular tissue alone would preserve the exact figure, and present a perfect skeleton of the whole, and of every one of its parts. Into the *areolæ*, or interstices of the cellular membrane, all other kinds of animal matter may be considered as infused. Thus, the bones are formed of an earthy salt, the phosphate of lime, infused in cells formed of cellular tissue. The muscles are bundles of fibres, inclosed in a sheath formed of cellular membrane. Every fasciculus of these fibres has a sheath of this tissue; and every individual fibre, which goes to the formation of a muscle, has an envelope of cellular membrane. The same tissue, also, forms sheaths for the nervous cords. These sheaths send fine processes within, which surround the bundles of nervous fibres, and connect them together. The greater part of the ligaments, tendons, and cartilages, are composed of cellular tissue. It even constitutes a very considerable part of the hair and nails. This tissue also penetrates into the interior of the solid viscera, as the liver, pancreas, and other glands, and the coats of the hollow organs, as the stomach, intestines, vessels, &c., where it serves the purpose of connecting and binding together the tissues of which they are composed.

The cellular tissue, then, it appears, occurs in two forms. In one, it constitutes the basis of all the solids of the body; in the other, it serves as a bond of union, by which the organs are connected together. The first, by some physiologists, is termed

the *parenchymatous;* the second, the *atmospheric* cellular tissue. The latter fills up the intervals or spaces between the organs; while the former enters into the texture of the organs themselves, and contains all the other tissues of which they are composed.

The cellular tissue, however, though entering into the composition of all the organs, which perform every variety of function, yet never loses its own character, which is every where the same; nor participates in that of the organ which it contributes to form. Though present in the nerves, and penetrating into the very recesses of these organs, yet it does not share in the sensibility which is the peculiar attribute of the nerves; and though it accompanies every muscle and every muscular fibre, it no where partakes of the irritability which belongs to these organs. Though it exists in the glands, it has no concern in the secretion of their peculiar products.

The cellular tissue appears to be composed of fibres of extreme delicacy, intersecting one another in every direction, so as to leave between them interstices, or little cells, from which it derives its name. According to Raspail, it is composed of a congeries of vesicles developed in successive series; those of cotemporaneous formation pressing on one another, and at length becoming cemented together, so that their parietes become confounded together. The cellular structure, however, appears only where the tissue is subjected to a slight distention, and it entirely disappears when the distending cause ceases to act; for the cellular tissue is extremely elastic and contractile, except in plants, in which it forms cells of regular shape, with firm walls. In animals, in the living state, it appears as a soft, loose, elastic, semi-fluid substance, of a grayish colour; sometimes it presents a slimy appearance. It gives passage to some blood-vessels and nerves, which, however, are destined to other parts, and are not spent on the cellular tissue itself. It is abundantly supplied with colourless vessels, and particularly lymphatics, which absorb the aqueous or oily fluid contained in its cells.

This tissue, as it exists in every part of the body, forms a connected whole, or an immense net-work, every where permeable to air. If air be forced into its cells in any part of the body, with a moderate continued force, it gradually penetrates and pervades the tissue, so that the whole of it becomes inflated. As it exists in the living body, its cells, where it enters into the composition of the organs, are filled with the parenchyma of these, and in other places, either with a watery halitus, or an oily fluid.

The uses of this tissue may be inferred from what has been said. It forms a basis for all the solid organs, and it connects the solid parts of the body together; and, by its softness and elasticity, and the oily fluid with which its cells are filled, it pro-

motes the mobility of the parts on one another. Its fundamental physiological property is *contractility*, or, *animal elasticity*, which it imparts to all the organs it contributes to form; and its chemical characterisic is its being composed chiefly of *gelatin*.

Out of the cellular tissue are formed a great variety of others, which may be regarded as modifications of it. These are *membranes* of all kinds, the sheaths of the muscles and nerves, vessels, and other organs.

The *membranes*, which are formed of the cellular tissue, constitute some of the most important structures of the body. The general covering of the body is formed of membrane. Each individual structure has its membranous covering. All the cavities, in which the principal organs are enclosed, are lined by membrane. The vessels are composed chiefly of membrane. Even the solid organs, as already observed, are formed of a basis of membrane, into the areolæ of which, as a mould, is infused the peculiar animal matter belonging to them respectively. Now, all these membranes are merely modifications of the cellular tissue.

The principal varieties of membrane, which require to be noticed, are the following, viz. the *serous*, the *mucous*, the *dermoid*, the *fibrous*, the *cartilaginous*, and the *osseous*.

1. *The serous membranes*. The serous membranes line all the closed cavities, or sacs of the body, and are reflected over the organs, contained in them. Thus, the cavities of the chest, the abdomen, the brain, and joints are lined by serous membrane. These membranes separate dissimilar or heterogeneous parts from each other. Wherever a cavity exists in the body, containing parts or organs differing in structure from the walls of the cavity, such cavity, as well as the contained parts, are lined by a serous membrane. Thus, in the cavity of the abdomen, which contains the great organs subservient to digestion; in the cavity of the chest, which contains the lungs; between the lungs themselves, where the heart is situated; in the ventricles of the brain, where the *plexus choroides* is found, we find, severally, a lining of serous membrane, which is reflected from the walls of the cavity, over the organs contained in it. The cavities of the joints belong to the same category, and, accordingly, the synovial membranes which line them, are classed with the serous membranes. The *bursæ mucosæ* belong to the same structure. The *arachnoides*, which lies between, and separates the *dura mater* and *pia mater* of the brain and spinal marrow, is also regarded as a serous membrane.

The serous membranes, it appears, enclose, chiefly, the organs of automatic or involuntary motion. They envelope the heart, the lungs, and the intestinal canal, and the glandular and other organs connected with it, and some of the organs of reproduc-

tion. According to Rudolphi, serous membranes line, not only the closed cavities of the body, but the interior of the vessels also, and the canals which open outwardly, as the alimentary canal and the air passages, forming a cuticle over the mucous membranes which line these passages, analogous to that which covers the external skin.

These membranes are of a shining whitish colour, and smooth on their free or inner surface, which is moistened with a watery halitus, from which they derive their name. On their attached, or external surface, they are rough, like condensed cellular membrane, and are connected with the walls of the cavities which they line by means of cellular tissue. They are extremely elastic and extensible, as appears from the shrinking of serous sacs after the removal of collections of water, or of any other cause which has distended them. They are said to be destitute of blood-vessels and nerves, and to consist merely of condensed cellular membrane, in which, it is asserted, the microscope cannot detect the least trace of a vessel. The serosity which exhales from, and moistens them, is merely an exudation from the vessels beneath them, and is probably transmitted by inorganic pores. The intense inflammation sometimes affecting the walls of the cavities which are lined by them, and which is usually referred to the serous membrane, is supposed, by some anatomists, to be seated in the tissues immediately subjacent to them.

The uses of the serous membranes are to separate heterogeneous parts or organs; and to diminish friction, and facilitate the motion or gliding of these parts upon one another by means of their moist and polished surfaces.

2. *Mucous membranes.* Another class of membranes, formed out of the cellular tissue, and possessing a higher degree of organization than the serous, are the *mucous membranes,* so called from the viscid fluid which it is their proper office to secrete. These membranes line all the cavities which open upon the surface of the body, as the digestive and urinary passages, the nasal cavities, and the air tubes. They enter into the structure of the different organs which are concerned in the prehension and assimilation of the aliments, in aerial respiration, and the secretion and excretion of the various fluids. They may be considered as the basis of the glands, into the substance of which they every where penetrate: the inner tunic of the excretory ducts, even to their radicles, where they anastomose with the capillary parenchyma of the glands, being always formed of mucous membrane. According to Rudolphi, these membranes have no free surface, but always lie between two others, having on their inner surface a thin serous tissue.

The mucous membranes, with scarcely an exception, form a continuous whole. That which lines the eyes and eyelids, is

connected by means of the nasal canal, with the membrane which invests the cavities of the nose. In the throat, the lining membranes of the mouth and nose pass into each other; and they detach a process which passes through the canal of Eustachius into the cavity of the tympanum. In the fauçes, the mucous membrane divides into two great branches, one of which passes through the larynx and trachea into the lungs, and furnishes a lining to the air tubes in all their branchings; the other follows the route of the pharynx and œsophagus into the stomach and intestines, which it lines throughout their whole extent. In the small intestines, it sends detachments to the liver and pancreas, through the biliary and pancreatic ducts, which penetrate, by the ramifications of these ducts, into the very parenchyma of these glands.

Another branch of the mucous membrane lines the passages of the urinary and sexual organs. In the male it invests the *urethra*, and bladder, and passes thence through the *ureters* into the kidneys; another branch passes into the *vesiculæ seminales*, and thence through the spermatic cord into the *testes*. In the female it lines the vagina and uterus, and passes thence through the fallopian tubes into the ovaries.

The branch of the mucous membrane which invests the urinary organs, apparently has no connexion with that which lines the alimentary canal. For the perineum, covered by the common integuments, intervenes between the outlets of the digestive and urinary passages. In some animals, however, these canals have a common outlet, and consequently the mucous membranes which line them are continuous with each other. This is the case with birds. In the mammalia, also, the skin which covers the perineum approaches, in its organization, to the mucous membrane. The mucous membranes which line the excretory ducts of the breast and the external ear, are isolated from the rest.

The mucous membranes, as before remarked, are more highly organized than the serous. They are of a loose, spongy texture, and of a reddish colour, and are largely supplied with blood-vessels and nerves. They are furnished with numerous small glandular bodies, called mucous glands or follicles. In a healthy state, these membranes are always covered with a slimy substance, which is secreted by them, and from which they derive their name. The uses of these membranes are to sheathe and protect the inner surfaces of the body, as the skin does the outer; and, by means of the mucus secreted by them, to screen these surfaces from the contact of irritating substances, which may either be introduced from without, or generated in the body itself. Like the cellular tissue, the mucous membranes are highly extensible and elastic.

3. The *skin* or *cutis*, which forms the outer covering of the body, forms another variety of membrane, which is a modification of the cellular tissue, and which bears a close analogy to the mucous membranes. About the orifices of the internal canals, the skin and the mucous membranes pass into each other, as in the lips, nostrils, eyelids, external ear, rectum, &c. Like the mucous membranes, the skin is largely supplied with blood-vessels and nerves, and in many parts with small glandular bodies, called sebaceous glands. On the face, and many other parts, it is thin and delicate; in the palms of the hands, and soles of the feet, and some other places, much thicker. It is covered, externally, by the cuticle, or *epidermis*, an inorganic membrane, destitute of vessels and nerves, wholly insensible, and easily renewed, if removed or destroyed. The inner surface of the cuticle is lined by a fine tissue, called the *rete mucosum*, by which it is united to the *cutis*, and which, by some, is regarded as a distinct membrane; by others, merely as compacted mucus. It is very soluble; and in the Ethiopian race, in which it is thicker than in the light-coloured varieties of the human species, according to Blumenbach, it may be completely separated both from the cutis and cuticle, and made to appear as a distinct membrane. It is the seat of colour in the human race, the cutis itself being white, and the cuticle, semi-transparent. The sebaceous glands of the cutis secrete a thin oily fluid, which is diffused over the skin, and preserves its suppleness and moisture. The skin is very extensible and contractile.

This membrane is one of the principal organs of relation; by means of which, a communication is established between us and the external world, and by which we obtain a great number of ideas of the qualities of external bodies, as heat, cold, hardness, form, distance, &c. To qualify it for this function, it possesses great sensibility, which it derives from the cerebro-spinal nerves, with which it is plentifully supplied. It also gives passage to fluids from the system under the form of insensible perspiration, or sweat, and is an absorbing, as well as an exhaling organ. It seems, also, to protect the system against the irritating contact of external bodies, and to modify the impressions received from them, so as to disarm them of their hurtful properties.

4. Another class of membranes, formed out of condensed cellular tissue, are the *fibrous*, so called from their texture. To this structure belong the *periosteum*, the *dura mater*, the *aponeuroses*, the *fasciæ*, the *perichondrium*, the *tunica albuginea* of the *testes* and of the *ovaries*, the coverings of the kidneys and spleen, and the *sclerotica* of the eye. The fibrous structure also appears under another form, that of thick bundles of different shapes, as in the ligaments and tendons.

The colour of this tissue is generally of a pearly white, with

a satin-like or argentine lustre. Its texture is essentially fibrous. The fibres which compose it are delicate and intimately connected together, so that it is difficult to separate them. It seems to consist principally of condensed cellular tissue. The fibrous tissue is sparingly supplied with vessels, particularly in adult age; but in the fœtal state, and in infancy, its vessels are much more abundant and conspicuous. Certain parts of this tissue, also, are highly vascular, as, for example, the periosteum and dura mater; while, in certain other parts, it seems to be wholly destitute of vessels. The existence of nerves in the fibrous tissue, has not been clearly demonstrated.

This tissue possesses but little elasticity, and scarcely any extensibility; but its strength and tenacity are very great. It possesses no irritability, and in a normal state, no perceptible sensibility. Yet the distention which precedes the rupture of the ligaments, and the wrenching of the same parts, in injuries, are productive of violent pain. In morbid states, the fibrous tissue is sometimes the seat of very acute sensibility.

The functions of this tissue, as it exists in the form of ligaments and tendons, are essentially mechanical. It chiefly serves to form bonds of connexion, by which the bones are united together, and the joints strengthened; and firm solid conductors of muscular motion to the bones, which the muscles are designed to move. In the form of membrane, it furnishes strong sheaths or envelopes to many parts, as the *corpora cavernosa*, the eye, the kidneys, spleen, testicles, the tendons, bones, and cartilages.

5. The *cartilaginous tissue* is another modification of the cellular, appearing to consist of condensed cellular membrane and gelatin. Cartilages are firm, smooth, highly elastic substances, of a pearly white colour, and which become semi-transparent by drying. With the exception of the bones, they are the hardest parts of the animal frame. They are destitute of blood-vessels, and neither nerves nor lymphatics have been discovered in them. They unite with great difficulty after wounds. Cartilages are invested with a fibrous membrane, called *perichondrium*. They differ from bones in containing no phosphate of lime, and in the want of cells and cavities for containing marrow.

Cartilages are divided into two kinds, the *permanent* and the *temporary*. The *temporary* are those which are destined to be converted into bone; for all the bones were originally cartilaginous. The *permanent* are those which are not destined to future ossification, though they are liable to a morbid process, by which they are converted into bone. Thus, the cartilages of the ribs, those of the larynx and trachea, and even the epiglottis, are sometimes found ossified. Naturalists have even observed examples of ossification in the cartilaginous fishes, in which, in

the normal state, the skeleton remains cartilaginous during the life of the animal.

The *permanent* cartilages are found in various situations, and perform various offices in the system. In some instances, they constitute the basis of organs; of which we have examples in the cartilage of the ear, that of the nose, and those of the larynx and trachea. Sometimes they exist between bones which are not susceptible of motion upon each other, as between the bones of the cranium; sometimes, between such as admit of a certain degree of motion upon one another, as the intervertebral cartilages, and those between the bones of the pelvis; they also tip the articular extremities of the long bones which move freely upon each other in the cavities of the joints. To these may be added the cartilaginous prolongations of the ribs.

6. The *osseous tissue*, which constitutes the bones, is the hardest part of the human body. The basis of it is cellular tissue, which is infiltrated with an earthy salt, the phosphate of lime. If this be removed, the bones appear as cartilages, and by long maceration, they are at last reduced to cellular tissue. The bones are formed from cartilages, as is evident from the process of ossification, in which the future bone always appears first in the form of cartilage. In the fœtal state all the bones are cartilaginous. The structure of bones belongs to that variety of the cellular tissue which is called fibrous. The fibres follow no regular course, but intersect each other in every direction. The osseous tissue, like the cartilaginous, is said to have no proper nerves; yet Mr. Swan has given us the view of a nervous cord passing directly into a bone. The blood-vessels of this tissue, which, in its early period of developement, are numerous, gradually diminish, and with them its powers of nutrition and reparation. The bones are covered with a fibrous membrane, called the *periosteum*, which may be considered as an expansion of the tendons of the muscles over the bones. The muscles are attached to the bones by means of the periosteum only. Into this membrane pass the nutritive blood-vessels of the bones, some of which branch over the periosteum, and others penetrate into the substance of the bones. In certain places, where no muscles are attached to bones, and no periosteum is formed, a distinct membrane is provided to supply its place. This is the case with the inner surface of the cranium, where a strong fibrous membrane supplies the place of an internal periosteum. The inner surface of the hollow bones is lined with a serous membrane, called the *periosteum internum*, or medullary web, which secretes the marrow. This is plentifully supplied with blood-vessels.

The bones may be divided into three kinds, the roundish or spongy bones, as those of the hands and feet, and the vertebræ;

the cylindrical or tubular bones, including those of the arms and legs; and the flat bones, as the shoulder-blades and the bones of the cranium.

The bones are of a yellowish white colour, and smooth externally; internally they present different kinds of structure. The broad flat bones consist of two tables, between which a cellular structure intervenes. In the cylindrical bones, the middle part is hollow, forming a tube, with firm, hard walls, but the two extremities are spongy or cellular. The cells and cavities are filled with an oily substance called marrow.

The bones form a connected system, which constitutes the basis of the whole frame. They are the hardest part of the body, and serve as the framework and support of all the soft parts. They serve as points of attachment to the muscles, or moving powers, and constitute levers of various kinds for the muscles to act upon, in executing the various motions which the body has the power of performing.

Ossification is frequently a morbid process, occurring in a variety of structures, and impeding the functions of the parts. Thus the coats of the arteries, the valves of the heart, the tendons, and even certain muscular parts, as the substance of the heart, sometimes become bony. The same structures are sometimes converted into cartilage.

II. Another constituent part of the system is the *muscular fibre.* To this appertains another of the elementary properties of life, viz. *irritability,* or the faculty of contracting or shortening itself on the application of certain stimuli. It is as peculiar, also, in its chemical constitution, as it is in its structure, and its vital properties, being formed almost wholly of concrete fibrin. Raspail applies his vesicular theory to the structure of the muscles, as well as to that of the cellular tissue. A muscular fibre he considers as an elongated imperforate vesicle, developed in the interior of one of a higher order, which has a similar origin. In this manner the whole organ may be considered as composed of different orders of vesicles, successively developed, and springing ultimately from a single vesicular germ. In the large bulky muscles of a stout man, Raspail conceives that the process of developement has proceeded further than in those of an emaciated subject; and that the increase in volume of these organs is owing, not merely to the deposition of interstitial adipose matter, but also to a developement of their own proper substance. Thus, if we suppose that in a muscle of an emaciated subject, we must pass through five successive orders of vesicles, before reaching the elementary muscular cylinder or fibre, it is easy to conceive that in a robust subject, the same muscle may have proceeded one step further in its developement, and that the fifth order, which constituted the ultimate filament in the extenuated

muscle, has, in the full-sized bulky organ, given birth to a sixth, which constitutes now the elementary fibres. It also appears, that each cylindrical cell not only reproduces its type by its internal surface, but may also germinate by its external. Hence we find in the same aponeurotic sheath, muscular fibres of different lengths.

By using a high magnifying power, Raspail discovered that each muscular fibre, consisting of an imperforate tube, contains within its cavity a spiral filament, which serves to keep its parietes apart, and by the approximation of its coils, to produce muscular contraction, a structure analogous to that of the ligneous fibres of vegetables.

The ultimate muscular filament is extremely minute, not exceeding, according to some physiologists, the fifth part of the diameter of a red globule of blood. The visible fibres into which the bundles of muscular flesh may be mechanically divided, are cylindrical in their shape, and of a reddish colour, which is supposed to be owing to the blood which they contain. The ultimate fibres are united into bundles, called *fasciculi*, or *lacerti;* and these, by their aggregation, form the fleshy masses which are called muscles. Every fibre and fasciculus is enclosed in a sheath of cellular tissue, and the whole muscle has an envelope of the same; so that the cellular tissue is largely incorporated into the substance of the muscles, to which it imparts its own peculiar property, animal elasticity.

The cellular substance, which thus exists between the fibres and fasciculi of the muscles, becomes thicker and more condensed, and constitutes a larger proportion of the whole mass, while the muscular fibres diminish, in receding from the middle and approaching the extremities of the muscles, where they terminate in tendons. And it is in this mode that the tendons are formed out of cellular tissue. For towards the extremities of the muscles this tissue becomes more condensed, and forms an increasing proportion of the whole mass of the organ, until the muscular fibres wholly disappear, and the whole cellular tissue belonging to each fibre and fasciculus, prolonged beyond the termination of the muscle, and condensed together, appears in the form of a silvery white cord, of a cylindrical or flattened shape, called tendon. The tendons then, it is evident, must be connected with every fibre of the muscles to which they belong. They are destitute of the irritability of the muscles, but are elastic like the cellular tissue, of which they are formed, and they consist principally of gelatin.

The muscles are the instruments by which most of the sensible motions of the system, both voluntary and involuntary, are executed.

III. The third constituent element of the structure of the body,

is the *nervous fibre*. This consists essentially of *albumen*, as the muscular fibre consists of *fibrin*, and the cellular tissue of *gelatin;* and it is endued with a distinct physiological property, *sensibility.*

A nerve consists of two elements, viz. a pulpy or medullary matter, i. e. the peculiar matter of the nerve, and a sheath which invests it, formed of cellular tissue. The medullary substance consists of bundles of nervous fibres, each covered with its own sheath of cellular tissue or membrane, and each also being divisible into a finer series, until we arrive at the ultimate nervous filament. This appears to be destitute of a cellular sheath; but the primitive nervous fibre, formed by an aggregate of filaments, is invested with a sheath, and every fasciculus in like manner has its own envelope of cellular tissue; and lastly, the nerve itself, formed by an aggregate of fasciculi, has a common sheath, which is called the *neurilema.* According to Fontana, the ultimate nervous filament is twelve times larger than the primitive muscular.

The nervous system, according to Raspail, has a vesicular origin. Every nervous branch is organized and developed exactly in the same manner as the branches of a plant. It is an elongated vesicle, which takes its origin from the external surface of the maternal branch, in which it is implanted. And the articulation of the two branches, viz. the maternal and the secondary, constitutes a ganglion, which, like the vegetable *nodus,* is a new centre of vitality.

Of nervous matter is formed the nervous system, consisting of the brain, spinal marrow, the ganglions, and the nerves themselves. Its elementary physiological property, as before remarked, is sensibility, which it communicates to all parts of the system to which nerves are distributed. The sensibility thus diffused throughout the system, has two principal centres or foci, viz. the *brain* and the *great solar plexus;* and it bestows unity and individuality upon the whole assemblage of organs and functions of which the living system is composed.

CHAPTER VIII.

THE COMPOUND STRUCTURES OF THE SYSTEM.

Out of the elementary tissues, which have thus been briefly described, viz. the cellular, muscular, and nervous, are formed the various organs which compose the system of the animal.

The principal of these are the bones, cartilages, ligaments, muscles, nerves, vessels, viscera, and organs of sense.

The two first of these, viz. the bones and cartilages, have already been sufficiently described, under the head of the osseous and cartilaginous tissues. The functions of these, together with those of the ligaments and tendons, are essentially mechanical.

The ligaments constitute a structure, the chief use of which is to connect the bones together into one system; though there are many other structures which resemble the ligaments, which are destined to very different uses; as, *e. g.*, the *sclerotica* of the eye, the *dura mater*, the *periosteum*, the *aponeuroses* of the muscles, the *fasciæ*, the white tunic of the testes and ovaria, and the proper coat of the kidneys and spleen. These, with the ligaments, constitute collectively, the *fibrous system*. The common character belonging to all these tissues, is a distinctly fibrous structure. In consequence of a deficiency of nerves, they possess scarcely any sensibility, except to mechanical violence of a certain kind, as, e. g., *wrenching;* and, as they contain scarcely any blood-vessels, they are of a white shining colour. They are very firm and compact in their texture.

The proper ligaments are of different shapes; some being round, some broad, and others forming sacs, as the capsular ligaments. They serve to connect together the articular ends of the bones in forming the joints.

The ligaments are intimately connected with the periosteum of the bones, as they spring from this membrane and are again inserted into it. In some few examples, however, they are connected, not with the periosteum, but with cartilages.

The capsular ligaments, which enclose the articulations, consist of two coats, of which the outer is fibrous, and the inner serous. The serous forms a closed sac, and is a secretory membrane, by which is prepared the synovial liquor.

The *muscles* constitute another very important class of organs, consisting of muscular fibres collected together in bundles by the intervention of cellular membrane, and plentifully supplied with blood-vessels and nerves. They are the organs of motion, and of the voice, and are divided into two classes—first, muscles of voluntary, and secondly, those of involuntary motion; or, as they are sometimes termed, muscles of *animal* and those of *organic* life. Those of the first class constitute the fleshy parts of the body. They lie more exteriorly, or towards the periphery; derive their nerves principally from the spinal marrow; act in the normal state only under the control of the will; are attached by both extremities to bones; and are the organs of the voluntary motions of the body.

The second class, or the muscles of *organic* life, are found in the interior of the body. These receive their nerves principally

from the ganglionic system. They are not attached to bones, and are hollow organs, which do not contract under the influence of the will, but in consequence of certain natural stimuli, applied directly to them. The heart, the stomach, intestines, bladder, and, according to some physiologists, the air tubes of the lungs, belong to this class of muscles. Animal motion, however, is not, in all instances, executed by muscles. The motions of the blood in the capillary vessels and veins, that of the lymph and chyle in the lymphatics, that of the different secreted fluids in the excretory ducts, the contractile motion of the cellular tissue and of several of the membranes formed out of it, as the skin, the serous and mucous tissues, &c. are not executed by a muscular structure.

The *nervous system* constitutes another very important system of organs, consisting of the brain, spinal marrow, ganglions, and nerves. Like the muscular system, it is divided into two great sections, one termed the nervous system of *animal*, the other that of *organic* life. The first consists of the brain and spinal marrow and the nerves proceeding from them; the second, of the system of ganglions and the nerves to which they give rise. The nervous system of animal life presides over cerebral sensation and voluntary motion. The nerves belonging to it, are connected, by their central extremity, with the brain or spinal cord, and by their peripheral, with the organs of sense, or the muscles of voluntary motion; and they are channels of communication between the centre and the periphery of the nervous system of animal life.

The nervous system of organic life, presides over organic sensibility and involuntary motion. Its nerves are distributed to the hollow viscera of the thorax and abdomen, and to the coats of the blood-vessels, which they accompany to all parts of the body. The functions of the circulation, of nutrition, secretion, exhalation, absorption, &c., are supposed to be under the control of this part of the nervous system.

The *vascular system* constitutes another very essential part of the human body. It embraces various organs, which differ in structure and in functions, but which agree in general in this respect, that they consist of cylindrical canals or tubes with membranous coats, which contain some kind of fluid, and do not open outwardly. By means of this system, certain substances, designed for nourishment or respiration, as aliment and the oxygen of the atmosphere, are introduced into the body, where, after undergoing certain changes, they are made to repair the waste in the organization occasioned by the operations of life. By the same system, materials unfit for nutrition, whether introduced from without, or developed in the body itself, are conducted to some excretory organ, by which they are afterwards discharged.

By the vascular system, the blood, the great excitant of the organs, and the source from which are derived the materials employed in the various processes of life, is distributed to all parts of the body, which are nourished and excited by it.

The vascular system is divided into three great branches, viz. the *arterial*, the *venous*, and the *lymphatic*. The first, or the arterial, carries red blood from the heart to all parts of the body; the second, or venous, brings back purple blood from all parts of the body to the heart again; and the third, the lymphatic, also called the absorbent system, carries white or colourless fluids from the interstices and periphery of the body, and from all the organs, into a large trunk, which opens into the venous system near the heart. The lymphatics, as yet, have been discovered only in the mammalia, birds, reptiles, and fishes. They originate from the various membranes, the basis of which is condensed cellular tissue, as the mucous, serous, synovial, and dermoid, as well as from the cellular membrane itself, which fills the interstices and forms the basis of the organs. They communicate with the venous system by means of the great lymphatic trunks, and, as some physiologists assert, by direct anastomosis with the veins; so that they are regarded as an appendage of the venous system. Their function is to absorb the nutritive fluid prepared by digestion in the alimentary canal, as well as other substances, which may come in contact with the external integuments of the body, and the mucous membranes. They also re-absorb certain parts of the various secreted fluids, and they are supposed to be the principal agents of the decomposition of the solid tissues and organs; the molecules of which they detach and absorb, convert into a fluid state, and convey into the mass of the venous blood.

The *arteries* are composed of three coats; first, an external, formed of condensed cellular tissue, and possessing considerable strength and elasticity; second, a middle, or the proper coat of the arteries, the real character of which is a subject of some controversy. It is a very firm, thick, and elastic tunic, composed of circular fibres, of a yellow colour, and possessed of little or no irritability. According to Berzelius, it is wholly destitute of fibrin, in which respect it differs essentially from the muscular tissues. The third or internal coat, is smooth and polished, and is said to be lubricated with a kind of serous exhalation.

The *veins* in their structure differ somewhat from the arteries. Like these, they are composed of three coats, an external, middle, and inner. The external consists of cellular substance, is dense, and difficult to rupture. The second, or middle, is considered as the proper coat of the veins. It is said to be composed of longitudinal fibres, but, according to Magendie, it contains a

multitude of fibres interlacing one another in all directions. Like the middle tunic of the arteries, it is insensible to the galvanic influence, and is not supposed to be muscular. It seems to be doubtful whether it contains fibrin or not.* The third or interior coat, is extremely thin and smooth, and serves to facilitate the motion of the blood by diminishing its friction. It is susceptible of great distention without being ruptured. It forms in the cavities of the veins numerous folds, which perform the function of valves.

The *lacteals* and *lymphatics* are composed of two coats only, viz. an external and an internal; the external, of a firm, fibrous nature; the internal, very thin and delicate. Like the veins, the lymphatics are supplied with numerous valves.

The *visceral system* comprehends the large organs contained in the great cavities of the thorax and abdomen, as the lungs, the stomach, intestines, liver, spleen, pancreas, &c. The heart is excepted, as belonging to the vascular system, and the brain, as being part of the nervous; and hence these two organs are not considered as being strictly *viscera*. The viscera are the most complicated parts of the animal system, with the exception of the organs of sense, which are properly appendages of the nervous system. They are the seats and the instruments of the great functions of *digestion* and *respiration*.

CHAPTER IX.

FLUIDS OF THE SYSTEM.

The fluids constitute much the larger proportion of the whole system. They are of various kinds, and perform very different offices in the animal economy. They may be distributed under three general heads, viz. I. those which serve for the preparation of the blood; II. those which are formed out of the blood; and III. the blood itself.

I. Those which serve for the preparation of the blood, are two, viz. the *chyle* and the *lymph*.

* The middle coat of the blood-vessels, is regarded, by many anatomists, as a distinct tissue of a fibrous structure and peculiar nature. It is either of a yellowish white, or pale reddish colour, and is called the vascular fibre. It contains no fibrin, nor does it respond to many irritations which excite muscular contraction, as galvanism, and mechanical irritation. It appears, however, to possess a peculiar vital contractility, which differs from muscular irritability. In the arteries, this tissue embraces these vessels circularly; in the veins, it is disposed longitudinally. The lymphatics are destitute of it.

The *chyle* is a thick, cream-like fluid, prepared from the aliment by the powers of digestion, and imbibed from the small intestines by a branch of the absorbent system, viz. the *lacteals,* and carried into the circulation by the thoracic duct. It is destined to repair the losses of the blood, to which fluid it bears a close analogy in its constitution and properties. Its final conversion into blood, is consummated in the lungs.

2. By the *lymph,* is meant a fluid which is formed in another part of the absorbent system, the proper *lymphatics.* As these vessels spring from all parts of the body, and are supposed to be the principal agents of the decomposition of the organs, the fluid contained in them must consist partly of the *debris* of all the solids, as well as of various fluids absorbed from the different cavities and surfaces of the system. These fluids, which are formed and deposited by a perpetual process of secretion, are subject to the action of the absorbents, so long as they remain in contact with any of the living tissues. Certain parts of them are imbibed by the lymphatics and blended with the molecules detached from the decomposing organs, and both are elaborated together into the fluid called lymph. This fluid is conveyed by the lymphatics into the common trunk of the absorbent system, the thoracic duct, where it is mixed with the chyle, and both are immediately afterwards carried into the torrent of the venous blood, near the heart. Like the chyle, the lymph contributes to repair the losses of the blood; but it is first subjected to the action of the lungs, in combination with the chyle and venous blood, and the whole compound fluid is converted by respiration into arterial blood. Like the chyle, too, the lymph bears a strong analogy to the blood in its composition and properties. These two fluids will be more particularly described hereafter.

II. The fluids formed out of the blood will be described under the head of the secretions.

III. The BLOOD is the most important of the animal fluids. This name is given to the scarlet or purple fluid, contained in the arteries and veins and the cavities of the heart. It is apparently homogeneous, but is in fact a fluid of a very compound nature, consisting of various ingredients, possessed of peculiar chemical and physical properties. It has a specific gravity somewhat greater than that of water, viz. from 1.053 to 1.126, according to Berzelius, a saline taste, and a faint animal odour.

The colour of the blood when flowing from a vein, is influenced by circumstances. If the arm has been long compressed by the bandage, it is darker than under other circumstances. The same is the case in persons afflicted with asthma or dyspnœa. In inflammatory and rheumatic affections, and in pulmonary consumption, it is of a brighter red.

As it exists in the blood-vessels, the blood is composed of

numerous red particles, of a globular or lenticular form, swimming in a colourless fluid, or of a solid and a liquid part. The latter has been called the *liquor sanguinis.* The former, to which the blood is indebted for its colour, has received the name of the *red globules.* The *liquor sanguinis* is, also, as will be presently seen, a complex substance. When kept at rest this fluid coagulates, forming a gelatinous mass of the same volume as when it was liquid, and which receives the shape of the containing vessel. Shortly after, the solid mass contracts in volume, forcing out of its surface and sides a yellowish liquid, which is the *serum* of the blood. In certain diseases, as rheumatic and inflammatory affections, the *liquor sanguinis* coagulates very slowly, giving time for the red globules, which have a greater specific gravity, in some measure to subside. The stratum of nearly colourless fluid which floats above, is the pure *liquor sanguinis,* cleared of the colouring principle, and may be removed and examined by itself.

So when the entire blood drawn from a healthy person is suffered to rest, in a short time it loses its fluidity, concretes into a solid mass, and soon afterwards begins to separate into two distinct portions. A yellowish transparent fluid oozes out of the coagulated mass, and when the process is completed, is found to constitute two-thirds or three-fourths of the whole. The coagulated part, which is of a red or dark brown colour, is called the *crassamentum* or *cruor* of the blood, and the fluid part the *serum.*

The *coagulum* or *cruor,* also, is found to consist of two parts; for, by ablution with water, it may be deprived of its red colour, a fact which proves that this colour depends on the presence of a separate principle. When thus separated from the two other constituent principles of the blood, viz. the serum and the colouring matter, the coagulum appears as a soft solid, of a whitish colour, insipid and inodorous, and of a greater specific gravity than water; and it sometimes presents a fibrous appearance, a circumstance from which it has received the name of *fibrin.* The colouring matter consists of minute globules of a red colour, soluble in water, and which are visible in the blood when viewed through a microscope.

Besides the constituent principles of the blood, already mentioned, this fluid contains a volatile matter, which is peculiar in every species of animal. This halitus, according to Berzelius, is a proximate element dissolved in serum. It is stronger and more abundant in men than in women and children; but in eunuchs, and in persons affected with *tabes dorsalis,* it is said to be absent.

At the moment of its coagulation, small bubbles of gas escape from the blood, which force a passage through the coagulum on their way to the surface.

The *serum* is a transparent liquid, of a light yellowish colour, of a saline taste, and of the odour of blood. It owes its taste to the presence of earthy and alkaline salts, which it holds in solution. Besides these salts, it contains a free alkali, as is evident from its changing vegetable blue colours to a green. But the property by which it is peculiarly distinguished, is that of becoming solid by exposure to heat. The temperature necessary to produce this effect, must be as high as 160° F. At this temperature, serum becomes a white, opaque solid, of a firm consistence, resembling the coagulated white of an egg. This property of becoming solid by exposure to heat, the *serum* owes to the presence of *albumen;* and a curious experiment of Magendie may serve to illustrate the affinity of the albumen of eggs with the serum of the blood. He injected the whites of five eggs, diluted with five times their volume of water, into the veins of a dog. The solution was somewhat viscid, yet the animal suffered no inconvenience from the experiment, and his blood, on examination, presented the usual characters of healthy blood. But a drachm of a *very viscid* solution of the same substance, injected into the carotid artery of the same animal, occasioned death in a few minutes. Serum preserves its property of coagulating even when diluted with a large quantity of water. Several other agents besides heat are capable of coagulating serum, as the mineral acids, alcohol, and some of the metallic salts. The action of the galvanic pile, also, coagulates it, and at the same time developes it in globules, which have a strong analogy to those of the blood. The coagulation of serum has been differently accounted for. By some chemists, it has been referred to the abstraction of its free alkali. Serum is a compound of albumen and soda, the latter of which is supposed to maintain the albumen in a liquid state. All agents, therefore, which are capable of abstracting the soda from the albumen, it is supposed, may indirectly cause it to coagulate, by removing the force which overcame its cohesive attraction. If we suppose the albumen to be kept in solution by means of the soda, it will be easy to understand why acids and alcohol coagulate serum. The action of heat is a little different. On the application of heat, the equilibrium of affinities, by which these elements are held together, is deranged; and the soda, which before was in a state of chemical combination with the albumen, is transferred to the water, while the albumen is left to assume a solid form.

The natural colour of the serum is liable to be changed by the presence of accidental substances. In jaundice it is of a deep yellow colour, which is derived from an impregnation with bile. It also acquires a yellow colour in persons who have been taking rhubarb. In blood drawn from a person who has recently

eaten a hearty meal, the serum has been found to exhibit the colour of turbid whey, owing, it is supposed, to the presence of chyle. In some cases it has been observed of a white colour, like cream, and sometimes has been found to contain globules. This appearance has been observed in the blood of persons whose digestive organs were disordered, and who had been subject to sickness, vomiting, and bad appetite. In young unweaned animals, as sucking puppies and kittens, the serum of the blood has sometimes been observed to be milk-white. Even white blood has also been seen to flow from the vessels of unweaned puppies. The blood of a goose was observed to be white by Ledel and Gendrin; Christison and others have witnessed the same fact; and Raspail mentions a phial of blood, which had the appearance of milk marbled with chocolate. This phenomenon he ascribes to the developement of an acid in the blood, (which in its ordinary state is alkaline,) causing a partial coagulation of the albumen in grumes, which, enveloping the colouring matter, clarifies the remaining liquid albumen, marbling it of a chocolate colour. The acid state of the blood in these cases, is proved by dropping a little upon the carbonate of lime, when it effervesces, and assumes a chocolate colour. The persons whose blood presents this appearance, Raspail observes are subject to vertigo. Alcohol, it seems, has in some instances produced the same effects, which Raspail ascribes to its developing acetic acid in the blood, by its action on the albumen.

Sometimes the white colour depends unequivocally on the presence of milk in the blood, as in the case of a man who had drunk a large quantity of this fluid before losing blood. Here chemical examination detected the presence of perfect milk in the blood drawn.

The same appearance has sometimes been owing to the presence of fat in the blood. In very fat persons, so much of this substance has sometimes been found in the blood as to form a crust on its surface, and even to admit of being removed by a teaspoon.*

Alcohol, as before mentioned, coagulates albumen; and Magendie says, that if an animal be made to swallow a large dose of alcohol, solidified albumen is found in his vessels after death. But it is a curious and important fact, connected with this subject, that alcohol may exist largely in the blood of living animals, without producing coagulation of the albumen; thus, the blood drawn from a man who had been drinking a large quantity of spirits, took fire on applying the flame of a lamp to it, and continued to burn several minutes.

* Thackrah and Adams.

Berzelius and Marcet have each analyzed the serum of the blood, with the following results:

Berzelius.		Marcet.	
Water,	905.0	Water,	900.00
Albumen,	80.0	Albumen,	86.80
Lactate and impure phosphate of soda,	4.0	Extractive matter,	4.00
Hydrochlorate of potash and soda,	6.0	Hydrochlorate of potash and soda,	6.60
Impure soda,	4.0	Subcarbonate of soda,	1.65
Loss,	1.0	Sulphate of potash,	0.35
		Earthy phosphate,	0.60
	1000.0		1000.00

A more recent analysis of serum by Le Canu, does not differ materially from the two former, except in the discovery of two new principles in this fluid; one a fatty, crystallizable matter; the other an oily substance.

The *coagulum* or *cruor* of the blood, is composed essentially of fibrin and colouring matter. When freed from the colouring matter, fibrin is a soft solid, of a whitish colour, without smell or taste, insoluble in water, not affecting the blue vegetable colours, and containing about four-fifths of its weight of water. Exposed to the air, it becomes dry, semi-transparent and brittle; and if in this state it be plunged into water, it gradually absorbs as much as it has before lost by desiccation, and resumes its former properties. By distillation, it furnishes a large quantity of carbonate of ammonia, and a voluminous charcoal, which is very difficult to incinerate, and which leaves a residue containing a good deal of phosphate of lime, a little phosphate of magnesia, carbonate of lime, and carbonate of soda.

One hundred parts of fibrin are composed of

Carbon,	53.360
Oxygen,	19.685
Hydrogen,	7.021
Azote,	19.934

Fibrin is the basis of muscular flesh. It possesses the power of spontaneous coagulation, and the blood owes its property of coagulating to the presence of this principle. Fibrin is considered by some chemists as a mere modification of albumen. According to Denis, it is albumen combined with different salts; but Magendie remarks, that an essential difference between albumen and fibrin consists in this: that a variety of substances solidify the former, whereas few possess the property of liquifying it, and that precisely the contrary is the fact in the case of fibrin. Thus, *nitrate of copper* coagulates albumen, but prevents the coagulation of fibrin. Fibrin is the basis of muscular flesh, but, according to Magendie, the fibrin of the blood differs from that of the muscles in being but slightly nutritive; whereas the latter is highly so.

Magendie asserts, that the blood owes its power of passing through the capillary system to the presence of fibrin, which renders it coagulable. Hence the coagulability of this element of the blood is necessary to the support of life. If any substance possessing the property of destroying the coagulability of the fibrin be injected into the veins, the blood will no longer be able to traverse the capillary vessels, but will become obstructed, either in the pulmonary capillaries, or in some others of still greater tenuity, producing local engorgements and extravasation in the tissues, and in short, all the consequences of capillary stagnation. A similar condition of the blood is a consequence of many fatal epidemics; it exists in asphyxia from carbonic acid, and is produced by the action of the hydrocyanic acid, and of some other poisons. The same physiologist expresses the singular opinion, that the fibrin is suspended in the serum in the form of minute vascular arborizations, forming the first degree or incipient state of organization.

The coagulation of the fibrin he considers as a higher degree of organization, and the clot of blood as an arborescent mass, forming a kind of delicately organized parenchyma, differing essentially from the albumen, the coagulation of which is the result of physical or chemical agency. The same property of fibrin is exemplified in the coagulum which obliterates the cavities of divided blood-vessels, in the formation of adhesions and false membranes, in all of which fibrin exists in an organized state. The cicatrization of wounds is effected by the same element of the blood, and hence when there is a deficiency of it in the vital fluid, wounds assume an unfavourable character, and refuse to heal. The well known influence of pure air and generous diet in promoting the healing of wounds and ulcers in such circumstances, is ascribed by Magendie to the power which these agents exert in increasing the fibrin or organizable element of the blood. The disposition to hemorrhage, and the difficulty of checking it, is probably to be ascribed in many cases to a deficiency of fibrin in the vital fluid. According to Meyer, the fibrin possesses a peculiar power of crystallizing. Under favourable circumstances, the red mass or crassamentum crystallizes in conical needles.

It is a remarkable fact, that in inflammation the proportion of fibrin in the blood is invariably increased; and acute rheumatism is the form of inflammation in which this increase is the greatest.

The remaining constituent of the blood is the *red globules*. When examined by the microscope, the blood presents the appearance of a fluid holding in suspension minute particles of a spheroidal or lenticular figure. According to some observers, these consist of a solid nucleus or central part, surrounded by a vesicle, which contains a fluid. It appears that the blood of all animals contains globules. These differ in shape and size in the

different species of animals. In the human species and the mammalia, in some of the fishes, in many of the mollusca, and in insects, they are round; in birds, in the amphibia, and in many of the fishes, they are of an elliptical shape. In the human blood the diameter of the globules is variously estimated by different observers; the estimates varying from one seventeen-hundreth to one six-thousandth part of an inch. Perhaps their diameter may be assumed at about one four-thousandth of an inch.

The latest microscopical observations on the globules of the human blood, represent them as circular, flattened bodies, having a depression in the centre; consisting of a central nucleus with an external envelope of a red colour.

Raspail considers the globules as composed of albumen, which has been dissolved in the serum of the blood by the aid of some menstruum, and is afterwards precipitated from it by its neutralization, or by evaporation. To illustrate their formation, he states that if a certain quantity of the white of eggs be put into an excess of concentrated hydrochloric acid, the albumen will at first coagulate and become white, but will afterwards dissolve in the acid, and assume a violet colour, which subsequently changes to a blue. If the acid be then decanted, or suffered to evaporate, a white powder will be precipitated, which, when viewed through a microscope, presents the appearance of very small spherical particles, of the same size with the globules of the blood, and which might easily be confounded with them. The number of the globules, he observes, will vary according to the quantity of the menstruum which evaporates in a given time, and many other circumstances.

The appearance of the central nucleus in each globule, he considers as, in most cases, the effect of an optical illusion; but that which is observed in the blood of frogs, he supposes to be owing to the successive solution of the different layers of the albuminous globule in the water in which they are diffused in making the experiment. As the external layers of the albuminous globule are the first to imbibe the water, they acquire a less refractive power than the central layers, which hence present a more opaque appearance than the external. When the most external layer is wholly dissolved, the next undergoes the same change, and so on till the globule is entirely dissolved and disappears.

Magendie, also, denies the existence of the central nucleus in the globules of human blood, though he admits of their presence in the globules of the blood of fishes and reptiles. If you take, he observes, some of the blood of one of these orders of animals, and examine the globules it contains with a microscope, you will distinctly perceive a swelling in the centre; afterwards dissolve the globules and examine the solution, and

no globules will be visible, but only the minute bodies which formed their nuclei, for these are insoluble in water. But water completely dissolves the globules of human blood; no vestige of them remains.

The chemical relations of the globules, according to Raspail, are identical with those of albumen. They are soluble in water, in ammonia, in the acetic and concentrated hydrochloric acids; and are coagulable by other acids, by heat, and by alcohol.

Arterial blood contains a greater number of globules than venous. The blood of birds also contains more than that of any other class of animals. The mammalia in this respect stand next to birds; and the blood of carnivorous animals appears to possess a greater number of globules than that of the herbivorous. In general, the quantity bears a certain relation to the degree of heat possessed by animals; the cold-blooded animals being those whose blood contains the smallest proportion.

According to Treviranus and some other physiologists, the globules of the blood possess the faculty of spontaneous motion. Haller says that the red globules possess three kinds of motion; viz. 1. Backwards and forwards in the vessels. 2. Towards wounded parts. 3. Towards large masses of red globules. Treviranus, with the assistance of a microscope, observed two kinds of motion in the blood while flowing from the veins of a living animal. One consisted in a whirling or rotatory motion of the globules, while the other manifested itself by a kind of tremulous contraction of the whole coagulum. According to Copland, Professor Schultz of Berlin has more recently confirmed the fact respecting the intestine motion of the globules, which, as he asserts, move on spontaneously, keeping at a distance from one another, and surrounded by envelopes of colouring matter. This power of the globules Copland attributes to the influence exerted by the ganglial nerves, which are plentifully distributed on the coats of the vessels. Another force which Copland supposes to act upon them and to influence their motions, is the attraction exerted by the different tissues with which they are brought into contact while circulating in the capillary vessels. The former of these forces keeps the globules in a state of constant motion and repulsion; the latter tends to bring them to a state of repose, and is exerted in the organic structures themselves, where the globules of the blood come into contact with them.

These two forces acting upon the globules, are also noticed by Andral, who remarks, that the blood when examined in the parenchyma of the organs by the aid of a microscope, has been compared to a kind of vortex, from which molecules are con-

stantly seen detaching themselves. These unite with and are lost in the solid tissues, while others are at the same time separating themselves from the solids and passing into the torrent of the blood. These motions of the red globules have been observed by several other physiologists, and of their existence there can be no doubt: but whether they are of a vital or mechanical kind, is a question on which there is much difference of opinion. Raspail regards them as the effects of currents in the serum, effects which, he says, may be imitated by suffering water, holding minute globules of the farina of potatoes, to flow through a fine tube, when, he observes, an innumerable multitude of limpid monads will be seen performing in all directions the most surprising evolutions. Magendie ridicules the idea of the spontaneous motion in the red globules as a chimera.

Another extraordinary kind of motion in the globules of the blood, has been observed several days after it has been drawn from the veins. These motions are rendered more conspicuous, by diluting the serum in which the globules float with a little water. The globules are then observed to move about in all directions, sometimes appearing to coalesce, then separating, and passing over and by the side of each other; in short, constantly altering their shape, position, and appearance.

It is remarkable that these motions are not visible until a few days after the blood is drawn; a fact, which seems to be wholly irreconcilable with the idea of their being of a vital character. Yet Messrs. Emerson and Reader, who witnessed and have accurately described these motions, ascribe them to a peculiar living action of the globules themselves. A curious discovery of Magendie seems to have ascertained their real nature. The French physiologist remarks, that when the globules are left to themselves for twenty-four or thirty-six hours, they assume a puckered look, and a multitude of monads or vibrions make their appearance in the serum and on the globules of the blood, moving on their surface, penetrating into their substance, and issuing from it by the edges. These globules gradually diminish in size, and at length disappear, as if devoured by the infusoria. These animalcula give rise to evident motions in the red globules, and were undoubtedly the cause of the motions observed by Emerson and Reader. When some fresh globules, extracted from newly drawn blood, were put into serum containing great numbers of infusoria, Magendie observes that the latter pounced on them with a sort of fury, and totally destroyed them in a very short time. Magendie also noticed another curious fact connected with this subject. In some blood mixed with sulphuretted hydrogen, he observed globules affected with a variety of extraordinary motions, oscillating in various directions with great rapidity, describing curved, straight, or irregular lines, just like the microscopic

monad. The cause of these motions he does not attempt to explain.

According to Poli, the red globules are affected with a kind of turgescence, which is greater or less according to the vigorous or enfeebled state of the animal, and of course must be of a vital character.

The red globules are the heaviest constituent part of the blood; a quality for which they are probably indebted to the presence of iron. An excess of them in the blood indicates an inflammatory or febrile diathesis. Their use is unknown, though it should seem that they are the most highly elaborated part of the vital fluid, for of all the elements of the blood, they are reproduced with the greatest difficulty. Hence the pale and exsangueous appearance, which is sometimes permanent, of persons who have experienced profuse or repeated losses of blood.

Besides the red globules there exists also in the blood, as one of its normal constituents, a considerable quantity of large white or colourless globules of a flattened or lenticular form, which adhere to the glass on which they are laid, while the coloured globules float about and oscillate in various directions. They are not affected by water, acetic acid, or ammonia, which dissolve the red globules.

According to Burdach, there is another kind of minute globules visible in the blood under the microscope. They present the appearance of a colourless, transparent, central part, of a vitreous look, surrounded by a dark red or blackish circumference, looking like a perforated disc, or like an iris with a light-coloured background behind the pupil. Sometimes they appear like minute glass spheres with dark rings around them. Their form is generally globular, but sometimes elliptical. Burdach regards them as air vesicles arising from the destruction of the red globules by water. In perfectly fresh blood he remarks they are generally wanting.

The colouring matter of the blood, sometimes called *hematosine*, is supposed by some to reside in the envelope of the red globules. By Brande it is considered as a peculiar animal principle, capable of combining with metallic oxides. He formed compounds of this colouring matter with oxide of tin. But the best precipitants of it are the nitrate of silver, and corrosive sublimate. Woollen cloths impregnated with either of these metallic salts, and dipped in an aqueous solution of the colouring matter of the blood, became permanently dyed. Berzelius and Engelhart attribute the colour of the blood to the presence of iron, in some unknown state of combination.

The existence of a large quantity of iron in the blood is well established; yet neither the gallic acid, the infusion of nutgalls,

nor the prussiate nor hydrocyanate of potash, produces in this fluid any precipitate, nor any change of colour, from which the presence of iron might be inferred. Hence Berzelius concluded that iron exists in the blood only in a metallic state. But the fact seems to be established by Rose and Raspail, that organic coagulable fluids are capable of withdrawing a metallic substance from the most powerful action of a reagent. Thus, a mixture of oil and the salts of iron, presents no signs of the presence of the metal, until several days after the mixture has been placed in the ferro-prussiate of potash, sharpened with an acid. Rose obtained the same result by mixing albumen or gelatin with the peroxide of iron.

The colouring matter is soluble in water. Soluble hematosine when perfectly dry is black, with a lustre like that of jet. In thin laminæ or in powder, it is of a red colour, and destitute both of smell and taste. With cold water, in which it readily dissolves, it forms a red liquor, which may be kept without change for months.

When dried and exposed to heat in contact with the air, it melts, swells up, and burns with a flame, leaving a coal of very difficult incineration. This coal burns with a disengagement of ammoniacal gas, and leaves the one hundredth part of its weight of ashes, composed of

Oxide of iron,	55.0
Phosphate of lime and a trace of phosphate of magnesia,	8.5
Lime,	17.5
Carbonic acid,	19.0

The colouring principle of the blood is supposed to be derived from respiration, because the globules of chyle and lymph, which are converted into blood by respiration, are destitute of it.

The analysis of the integral blood, according to Le Canu, presents the following results:

Water,	780.145	786.590
Fibrin,	2.100	3.565
Albumen,	65.090	69.415
Colouring matter,	133.000	119.626
Crystallizable fatty matter,	2.430	4.300
Oily matter,	1.310	2.270
Extracted matter soluble in alcohol and water,	1.790	1.920
Albumen combined with soda,	1.265	2.010
Chloruret of sodium and potassium, alkaline phosphates, sulphates and sub-carbonates,	8.370	7.304
Sub-carbonate of lime and magnesia, phosphates of lime, magnesia and iron, peroxide of iron,	2.100	1.414
Loss,	2.400	2.586
	1000.00	1000.00

The coagulation of the blood has been attributed to various causes, as, e. g. its cooling on being drawn from the vessels, the contact of the air, rest, &c. None of these causes, however, is sufficient to produce this effect. Hewson froze fresh blood by exposing it to a low temperature, and afterwards thawed it. It first resumed its fluidity, but afterwards coagulated in the usual manner. But Magendie found that blood exposed to a temperature of 14° Réaumur, coagulated into a very firm clot before congelation took place, but on raising its temperature it *did not regain its fluidity.* It has also been ascertained by experiment, that blood will coagulate when deprived of the contact of the air, and subjected to agitation. In the exhausted receiver of an air-pump its coagulation is even accelerated. But if a bottle be completely filled with blood, recently drawn, and the mouth then accurately closed with a tight stopper, coagulation is retarded. Coagulation is influenced by the rapidity with which the blood flows from the body. According to Scudamore, blood slowly drawn from a vein coagulates more rapidly than when taken in a full stream. He also found that coagulation is hastened by heat, and retarded by cold.

The action of oxygen upon the blood promotes coagulation, while that of carbonic acid retards, without preventing it.

The division of the 8th pair, according to Magendie, deprives the blood of its power of coagulating.

Certain saline substances, as, a solution of common salt, muriate of ammonia, nitre, or a solution of potash, prevent a coagulation of the blood; while alum, and the sulphates of zinc and of copper, promote it. Electricity, according to Scudamore, does not prevent coagulation. Blood, subjected to electric shocks, was found to coagulate as quickly as that which was not electrified; and the blood was always found coagulated in the veins, in animals killed by powerful galvanic shocks.

Scudamore considers coagulation as connected with the disengagement of carbonic acid, which is most active at the commencement of coagulation, and ceases when this process is completed. Hence, whatever retards the extrication of carbonic acid, obstructs coagulation. The blood coagulates more rapidly in proportion as it is heavier and richer in coagulable matter, as in strong healthy persons. A firm texture of the coagulum indicates great vascular activity.

During the coagulation of the blood, the temperature of the mass is said to rise. Dr. Gordon estimated the rise of the thermometer at six degrees. Dr. Davy, however, regards the increase of temperature from this cause as very trifling.

Raspail accounts for the coagulation of the blood, by referring it to the neutralization or evaporation of some menstruum, which maintained the albumen in a liquid state. This menstruum he

supposes to be soda and ammonia. On this principle, he observes, the spontaneous coagulation of the blood presents no insuperable difficulty. For, the carbonic acid of the atmosphere, and the carbonic acid which is formed in the blood itself by the absorption of oxygen, combines with and saturates the menstruum of the albumen, which is conseqently precipitated in the form of a coagulum. The evaporation of the ammonia, which is another menstruum of the albumen, and that of a part of the water of the blood, liberates another portion of dissolved albumen, and increases the quantity of the coagulum.

Raspail, on the same principle, accounts for the precipitation of the albumen in the form of the globules of the blood, which he considers as identical with albumen. The absorption of the aqueous part of the blood by the tissues nourished by it, and perhaps the saturation of the alkaline menstruum of the albumen by the residue of nutrition constantly passing into the blood from the same tissues, occasion a regular precipitation of albumen in the blood, in the form of small globules.

Raspail then regards the blood as analogous to vegetable fluids, and containing essentially the same principles, viz. albumen, water, and various saline substances, with a colouring principle. The albumen exists in two states, viz. in solution, in which it is held by an alkaline menstruum, but coagulable by the saturation of the menstruum, and secondly, in the form of globules.*

The coagulation of the blood, however, is regarded by the most enlightened physiologists, as a vital phenomenon, and as not depending on any physical cause. "The blood is supposed either to be endowed with a principle of vitality, or to receive from the living parts, with which it is in contact, a certain vital impression, which, together with constant motion, counteracts its tendency to coagulate."

Copland ascribes the coagulation of the blood principally to the agency of the red globules, resulting chiefly from the loss of the vital motion which these globules possess in the vessels, and that of the attraction existing between the colouring envelopes and the central globules contained in them. This attraction ceases soon after the blood is removed from the veins; and the

* The following table exhibits his views of the composition of the blood:

BLOOD.

1. Globular *albumen.*
2. *Albumen* in solution, but coagulable by the saturation of the menstruum.
3. *Oil* in small quantity.
4. *Hydrochlorates*, *acetates*, and *phosphates* of ammonia, soda, potash, lime, magnesia, and iron.

COLOURING MATTER.

5. Iron and potash combined with albumen, which holds it in solution.

central bodies, freed from the coloured envelopes, are left to obey the attraction, which tends to unite them; in uniting, they form a network, in the meshes of which the colouring matter is entangled; and thus the phenomena of coagulation are produced.

The blood exhibits a pulsating motion in the incubated egg before the formation of the heart, so that it possesses a power of motion in this initial stage of fœtal life wholly independent of the heart, and perhaps derived from its own inherent nature. Indeed, some time after the heart is formed out of the blood, it appears pale and bloodless, nor does it pulsate or move like the rest of the body of the embryo. The speck of blood which is thus discerned four or five days after incubation, is so minute that it disappears during its contraction, and is only visible during its expansion, when it appears of the size of the point of a needle, and of a red colour.

According to Burdach, the blood also possesses a great power of expansion, as is evinced by several facts. This expansive power is connected with its vitality; for after death the whole mass of the blood appears to occupy much less space than during life. For example, in the dead body the arteries are empty, the heart and capillaries contain but little blood, and the veins less than in the living state; and the great venous trunks, into which the blood appears to be chiefly collected, are by no means much distended. Now during life the whole vascular system is full of blood, a fact from which, when compared with the preceding one, it seems to follow that the blood is more expanded, and occupies more space in its living state, than after death. The following experiment by Rosa appears to confirm this conclusion. He tied up an artery in a living animal when filled with blood. He afterwards cut out the enclosed part, and found that when it was cold, it shrunk to one-third of its former diameter, so that the volume of the dead compared with that of the living blood, was in the ratio of one to nine. So in the living state, the volume of the blood, he says, appears to observe the same ratio with that of the activity of the living power.

Bellengeri made some interesting experiments on the electricity of the blood, of which some of the results are the following, viz.

In the phlegmasiæ, the electricity of the blood is evidently diminished, but increases again as the disease abates. In chronic diseases the opposite condition obtains. In many cases of intense inflammation the electricity is negative. When the blood forms the inflammatory crust, its electricity is less than in its healthy state. When the blood shows a higher degree of electricity than in its normal state, the buffy coat never forms on it. At the commencement of venesection the blood is darker, thicker, less fluid, and *less electrical* than at the end of the process.

The blood furnishes the elements of nutrition to all the tissues and organs of the body; and recent analyses of this fluid have ascertained in it the presence of many of the peculiar forms of animal matter of which the organs are composed. Vauquelin discovered in the blood a considerable quantity of a fatty substance, which was at first supposed to be fat, but which was afterwards ascertained by Chevreul to be the peculiar substance of the brain and nerves. It differs from fat, and all other substances of the same nature, in containing azote.

Prevost and Dumas demonstrated the existence of urea, a peculiar animal matter found in the urine, in the blood of animals whose kidneys had been extirpated. Cholesterine, and some of the other elements of the bile, have been discovered in the serum of the blood. The fibrin which exists in this fluid is identical with the muscular fibre; its albumen is the basis of a great number of membranes and tissues: the fatty substance, before mentioned, combined with albumen and ozmazome, forms the nervous system; and the phosphates of lime and magnesia, which exist in the blood, constitute a great portion of the substance of the bones.

CHAPTER X.

CHEMICAL ANALYSIS OF THE ORGANIZATION.

It has already been observed, that organized matter consists of two classes of elements, viz. one *chemical*, the other *organic*. The chemical, are the ultimate elements into which organized substances may be reduced by destructive analysis; as, oxygen, hydrogen, carbon, azote, &c. The organic are the proximate elements, which are formed out of the ultimate, not by the chemical powers of matter, but by the operation of the organic forces. These are albumen, fibrin, gelatin, ozmazome, &c. All animal matter may be analyzed proximately into these elements. The chemical forces tend to destroy these forms of matter, and to reduce them to the ultimate elements.

The Ultimate Elements.

The ultimate ponderable elements of animal matter may be divided into *non-metallic* and *metallic* substances.

I. The non-metallic elements are oxygen, hydrogen, carbon, azote, phosphorus, sulphur, chlorine, and fluorine. (Berthold.)

II. The metallic elements are, 1. The bases of the alkalies,

viz., potassium, or kalium, sodium, and calcium. 2. The metallic bases of some of the earths, viz. magnesium, silicium, and aluminum. 3. The ponderous metals, iron, manganese, and copper.

Of these, the four first of the non-metallic elements, viz. oxygen, hydrogen, carbon, and azote, exist in vastly the greatest proportion, and perhaps may be considered, as the only essential elements of animal matter.

Oxygen enters very largely into the composition of animal matter. It is a constituent part of all the fluids and solids of the body. It is an essential element of all the proximate elements, for these may all be divided into organic oxides and acids. In combination with hydrogen, it forms the watery basis of all the fluids, which constitute, as it has been computed, nine-tenths of the weight of the body. In union with carbon it forms carbonic acid, which exists in the blood, and is exhaled abundantly from the lungs in respiration, and from the skin. With phosphorus it forms the phosphoric acid, which exists largely in the bones in combination with lime, and is one of the constituents of healthy urine. With the metalloids it forms potash, soda, and lime. It also enters into the composition of the organic elements, as albumen, fibrin, gelatin, and mucus. The oxygen which exists in the body, is derived partly from the food and drink, and partly from respiration. It is eliminated from the system by all the excretions, particularly by sweat, urine, and respiration.

It is remarkable, that in certain fishes, the air contained in the swimming vesicle, is pure oxygen gas. This is the case with the fishes, which live near the bottom of the water, and swim near the ground.

Hydrogen is another principle which exists in all the fluids, and several of the solids of the body. It constitutes one element of the watery basis of the fluids. It predominates in venous blood, as oxygen does in arterial. It exists largely in the bile; is one of the elements of fat and oil; and is often developed in a gaseous form in the intestinal canal, in enfeebled states of digestion. Combined with chlorine, it forms the hydrochloric acid, which exists in many of the animal fluids, in combination with soda. Hydrogen is introduced into the system by the aliments, and is eliminated by cutaneous and pulmonary exhalations, by the excretions of the kidneys, alimentary canal, and liver. In the process of putrefactive decomposition, it combines with sulphur, and sometimes with phosphorus, forming, with them, two fetid gases, the sulphuretted and phosphuretted hydrogen.

Carbon. This element abounds in the vegetable kingdom, but is also to be found largely in animal substances. It is one of the elements of animal oil or fat, and of the quaternary animal

oxides, albumen, fibrin, gelatin, and mucus. It exists largely in the bile, and in venous blood. Most animal substances by combustion develope a considerable quantity of carbon. It is received by the aliments, and is eliminated by respiration, by cutaneous transpiration, and by the secretion of the liver. It is constantly developed by the processes of life, accumulates in the venous blood, and is discharged from it principally by respiration.

Azote. This principle exists largely in animal matter, and is regarded as one of its principal chemical characteristics. It is true, however, that a few plants contain it, particularly the mushroom tribe. It abounds also in the pollen of plants, and in the vegetable principle, gluten, and is one of the elements of the vegetable alkaloids, quinine, strychnine, &c. But it exists almost universally in animal substances, and may be regarded as one of the essential elements. All the organic elements of animal matter contain azote; but it exists most abundantly in fibrin, and, consequently, in the muscular flesh, which is formed principally of this element. The substance of the brain and nerves contains a less proportion of azote. The peculiar smell of burning animal matter is owing chiefly to the presence of this principle. In the putrefaction of animal substances, the azote, disengaging itself from the other elements, combines with the hydrogen, forming a binary compound, *ammonia,* which is one of the characteristic results of animal decomposition.

Azote is received into the system chiefly with the food, particularly with that which is derived from the animal kingdom, and from the leguminous plants, and the seeds of the *cerealia.* It is also believed to be introduced into the blood by respiration, in which, it appears to be ascertained, there is an absorption of azote. Its discharge from the system is effected principally by the secretion of the kidneys, as it exists largely in healthy urine; but partly by respiration, in which there appears to be an exhalation, as well as absorption, of azote. It always exists in combination with other elements in the animal system, except in the vesicle of certain fishes which swim near the surface of the water, in which it is found in a pure state.

Of these four essential elements of animal matter, three, when in an uncombined state, are aeriform bodies; and the effort which they make, as they exist in animal substances, to abandon the solid form, and resume their natural state as gases, an effort which is increased by the external heat to which animal substances are exposed, and by their own organic heat when in a living state, promotes the tendency to decomposition of animal matter.

Phosphorus. This principle exists both in animal and vegetable substances, but more abundantly in the former. It is present in

the blood and the brain, and, indeed, in nearly all parts of animal bodies, but is contained in the greatest proportion in the bones, combined with oxygen, with which it forms phosphoric acid. It always exists in combination, generally in the state of phosphoric acid. It is evacuated chiefly by urine, which contains a considerable quantity of phosphoric acid, some of it free, and some in combination with bases. During animal decomposition, a part of the phosphorus combines with hydrogen, forming the fetid gas, phosphuretted hydrogen. The phosphorescence of putrefying animal matter, is supposed to be owing to some inflammable compound of this kind. The extraordinary phenomenon of the spontaneous combustion of the human body, has been attributed by Treviranus, to an accumulation of phosphorus in the system, owing to some obstacle to its regular excretion by the kidneys and other outlets. The body, it is supposed, may at length become so highly charged with it, as to be rendered extremely combustible.

Sulphur. This is another principle of animal substances which always exists in combination with other elements, as soda and potash. It exists particularly in albumen, and in the hair and nails, and also in muscular flesh. It is extricated in the intestines in combination with hydrogen, and then discharged from the system. It also, sometimes, passes off by cutaneous transpiration. The fetor of foul ulcers is occasioned partly by an evolution of sulphuretted hydrogen; and the same gas is supposed by some to be the vehicle of infection in the hospital gangrene.

Chlorine exists in most of the animal fluids in combination with hydrogen, forming the hydrochloric acid. This is present in a free state in the gastric fluid, and in combination with soda and potash in the blood and bile. It exists, also, in the urine, in the sweat, milk, saliva, synovial fluid, &c.

Kalium or *Potassium* exists very sparingly in the system, and always in combination with oxygen, i. e. in the state of *potash.* Combined with muriatic acid, potash is present in the blood, and several of the secreted fluids, as the bile, urine, sweat, milk, &c. In combination with the phosphoric acid, it exists in the brain. It is much more abundant in plants than animals.

Sodium. This metalloid, in combination with oxygen, is much more abundant in animal substances than *kalium.* As soda, it exists in the blood, mucus, saliva, bile, muscular flesh, bones, milk, and other animal substances, in combination with the carbonic, phosphoric, sulphuric, muriatic, and lactic acids. It is more common in animals than in plants.

Calcium, in the form of lime, exists largely in the bones, and sparingly in the muscles and brain. It is generally combined with the phosphoric acid, as in the bones, but sometimes

with the carbonic acid, forming the phosphate and carbonate of lime.

Silicium is found, though very sparingly, in some kinds of animal matter. It exists as silex in the human hair, and in the urine.

Magnesium exists in animal and vegetable substances, especially in bones, and in some animal fluids. In combination with phosphoric acid it is found in the blood, in the substance of the brain, and in human milk.

Iron. This metal is pretty extensively diffused in animal bodies; especially in the blood of red-blooded animals, and in the *pigmentum nigrum.* In what state it exists in the blood is not known. It is supposed by some physiologists, in some indeterminate state of combination, to form the colouring principle of the red globules of the blood.

The Organic or Proximate Elements.

The proximate principles of animal matter are formed by various combinations of the ultimate elements, by the influence of the vital or organic forces. These principles are, for the most part, quaternary compounds of oxygen, hydrogen, carbon, and azote. Some of the acids found in animals, form an exception to this general fact, being formed of only three elements.

The organic elements may be divided into two classes, viz: *acids* and *oxides.* In addition to these, vegetables possess a peculiar kind of proximate principles, which are not found in animals. These are the recently discovered vegetable alkalies.

1. The organic *acids* found in the human system, are the *acetic,* the *oxalic,* the *benzoic,* and the *uric.* The three first are common to the animal and vegetable kingdoms, and consist of three elements only, viz: oxygen, hydrogen, and carbon. The *acetic,* called also the *lactic* acid, exists in milk, urine, and in many other animal fluids. The *oxalic* exists in some of the urinary calculi, particularly the mulberry calculus. The *benzoic* acid has been discovered in human urine.

The *uric* acid consists of four elements, oxygen, carbon, hydrogen, and azote. It is a constituent part of human urine, and of that of many other animals, as birds, reptiles, and insects.

2. The organic *oxides* are numerous, both in the vegetable and animal kingdoms, and differ widely from one another in their properties. Some of them consist of three elements, oxygen, carbon, and hydrogen; others, of four, containing azote in addition to the three former.

The *ternary* oxides found in the animal kingdom, are *sugar, resin,* and *fixed* and *volatile oils.*

Of *sugar,* there are two varieties found in the human system.

One, the *sugar* of milk; the other, a morbid product, existing in the urine of persons affected with diabetes.

The *sugar of milk* is obtained from the whey, by evaporating it to the consistence of syrup, and allowing it to cool. It is afterwards purified by means of albumen and crystallizing it again. In many respects it differs from the sugar of the cane, though possessing a sweet taste. It is not susceptible of the vinous fermentation; and may be converted by the action of the nitric acid, into the *saccholactic* acid; a property in which it differs from every other kind of sugar.

The *sugar of diabetes* exists in the urine of persons affected with this disease. It may be obtained by evaporating diabetic urine to the consistence of a syrup, and keeping it in a warm place for several days. In its properties and composition it appears to be identical with vegetable sugar.

A peculiar *resin* exists in the bile.

Of *fixed oils*, fat and the marrow of the bones are examples.

Volatile oils are found in some of the inferior animals, but not in man.

The *quaternary* compounds, formed of oxygen, carbon, hydrogen, and azote, are the most important proximate principles of animal matter. Among those which are most generally diffused, and which enter more or less into the composition of almost all animal bodies, are *albumen*, *fibrin*, *gelatin*, *mucus*, and *ozmazome*. Besides these, there are several others which are less common, as *caseine*, *urea*, *hematine*, the black matter of the eye, *cholesterine*, *picromel*, &c.

The first of these, *albumen*, is, of all substances, the most generally diffused in the animal economy. It exists both in a liquid and in a solid form. Combined with a greater or less proportion of water and a little saline matter, it constitutes the white of eggs, from which it derives its name, *albumen;* it forms, also, the serum of the blood, the aqueous fluid of the cavities and cellular tissue, and the fluid of dropsies. It constitutes the principal part of the synovial fluid, and it exists in the chyle and lymph. It forms the fluid of blisters and burns, and that which is contained in the hydatid. It is a colourless, transparent substance, without taste or smell, coagulable by heat, by alcohol, ether, concentrated sulphuric acid, some of the metallic salts in solution, and an infusion of tannin. Exposed to a certain degree of heat, (about 160° F.) it coagulates into an insoluble mass.

According to Raspail, albumen is composed of two heterogeneous substances, one an organized insoluble tissue of a cellular structure, the other a liquid contained in the cells of the former. This, he says, may be verified by the simple experiment of shaking together distilled water, and the fresh white of an egg.

The agitation will make the water milky, and there will be visible, even to the naked eye, a considerable quantity of fragments of white membranous tissues. These membranous flakes may be easily separated by filtering the water, which will pass through the filter perfectly limpid, carrying with it the soluble parts of the albumen, but leaving behind the organized tissue in the form of a white, elastic, and glutinous mass, insoluble in water. The filtered water, exposed to evaporation, leaves behind a solid residue of a yellowish colour. If exposed to heat it becomes milky and coagulates, and in short presents all the characters of liquid albumen. In common air it putrefies, and generates multitudes of infusory animalcula of the genus *monad.*

The insoluble tissue is not visible until the albumen is shaken with water, because it possesses the same refractive power as the soluble part contained in its cells. But water, by diluting the liquid part, communicates to it a different refractive power from that of the tissue, and then becomes milky, because it contains two substances, which refract unequally the rays of light.

Solid albumen is a white, tasteless, elastic substance, insoluble in water, alcohol and, oils, but readily dissolved by alkalies. It constitutes the basis of the substance of the nerves, and brain, and is contained in several of the tissues of the body, as, e. g. the skin, glands, and vessels. It exists in the hair and nails; and morbid growths and tumours are composed principally of it.

Albumen is composed of

Carbon, ...	52.883	or	17	equivalents.
Oxygen, ...	23.872		6	do.
Hydrogen, ...	7.540		13	do.
Azote, ...	15.705		2	do.

It also contains a small quantity of sulphur; since it blackens silver, and in a state of decomposition, exhales sulphuretted hydrogen gas. The physiological property which corresponds with albumen is *sensibility.*

Fibrin is a principle which enters largely into the composition of the blood, chyle, and lymph, and is the basis of muscular flesh. It possesses the property of spontaneously coagulating, and it is owing to the presence of fibrin that the blood coagulates when drawn from the living vessels. In its coagulated state fibrin is a solid whitish substance of a fibrous appearance, and may be easily drawn into threads. It is destitute of smell and taste, and insoluble in water. It may be obtained by stirring fresh blood with a stick until it coagulates, and then washing the fibres which adhere to the stick with cold water, so as to dissolve out the red globules. In its chemical composition and many of its properties it resembles albumen, but differs from it in coagulating at all temperatures.

Fibrin is composed of

Carbon,	53.360	or	18	equivalents.
Oxygen,	19.685		5	do.
Hydrogen,	7.021		14	do.
Azote,	19.934		3	do.

From this analysis it appears that fibrin is more highly azotized than *albumen*. The physiological property which corresponds to it is *irritability*.

Gelatin is another element of almost all the solid parts of the body; but, what is remarkable, it exists in none of the fluids. It is a substance distinguished from all other animal principles by its readily dissolving in warm water, and forming a bulky, tremulous solid on cooling. When dried, it forms a hard, semi-transparent, brittle substance, with a shining fracture. One part of gelatin dissolved in one hundred parts of warm water becomes solid on cooling, forming a hydrate of gelatin.

The well-known cement, glue, which is prepared from the skins and hoofs of animals by boiling them in water, and evaporating the solution, is an impure gelatin. The isinglass of commerce, prepared from the sounds of the sturgeon, is a very pure species of this principle.

Gelatin forms the basis of the cellular tissue and its modifications, and exists in the skin, cartilages, ligaments, tendons, and bones. As it is not present in the blood, nor indeed in any of the animal fluids, it is a question by what means it is formed in the system. This question we have at present no sufficient means of answering. It is probably, like fibrin, a mere modification of albumen. Raspail conceives that it does not exist as such in the system, but is the result of the action of heat on the tissues employed in preparing it.

It is composed of

Carbon,	47.881
Oxygen,	27.207
Hydrogen,	7.914
Azote,	16.998
	100.000

The property which corresponds to gelatin in the system is *animal elasticity*.

Osmazome. This is another element which is found in all the animal fluids, and in some of the solid parts of the body, as the brain and the muscular fibre. It exists in the flesh of most adult animals. It is a reddish brown substance, of an aromatic smell, and of a strong and agreeable taste. The flavour and smell of beef-soup are owing to the presence of osmazome. The strong taste of roasted meat, also, is supposed to depend on osmazome. It is distinguished from other animal principles by its solubility

in water and alcohol, either cold or hot, and by not forming a jelly when its solution is concentrated by evaporation. According to Orfila, it possesses no nutritious powers, but is tonic and stimulating.

By some physiologists, osmazome is regarded as a peculiar extractive matter of flesh; but by Berzelius it is considered as a compound formed of a peculiar animal matter, combined with lactate of soda, and by Raspail, as an impure combination of albumen and acetic acid.

Mucus. This is a secreted fluid, which lubricates the surface of the mucous membranes. In a solid state it enters into the composition of some of the hard parts of the body, which are destitute of sensibility, as the nails, hair, cuticle, and horny parts, which consist chiefly of inspissated mucus. The scales, feathers, and wool of different animals contain a good deal of mucus. The *rete mucosum* is supposed to be formed of compacted mucus. In union with water, mucus is a transparent, viscid, ropy fluid, without odour or taste. Nitric acid at first coagulates, but afterwards dissolves it. In its dry state it is insoluble in water. In hot water it imbibes so much of the fluid as to swell and become softened. The acids are its true solvents. It contains a good deal of azote.

Caseine. This substance exists only in the milk of the mammiferous animals, and is obtained from this fluid after it has been coagulated. After the removal of the cream, the curd must be well washed with water, drained on a filter, and dried; and it then constitutes the caseine. This principle derives its name from its being the basis of cheese. It is a white, insipid, inodorous substance, of a greater specific gravity than water, and is highly azotized, and very nutritious. When decomposed by fire, it yields a large quantity of carbonate of ammonia.

Caseine appears to have a strong resemblance to albumen, particularly in being coagulated by acids.

It is composed of

Carbon,	59.781
Oxygen,	11.409
Hydrogen,	7.429
Azote,	21.381
	100.000

Urea is a matter which exists in human urine and in that of quadrupeds. It may be procured by evaporating fresh urine to the consistence of a syrup, and gradually adding to it concentrated nitric acid, till it becomes a dark coloured, crystallized mass. This is to be well washed with ice-cold water, and then dried by pressure between folds of blotting paper. The nitrate of urea is afterwards to be decomposed by a strong solution of

carbonate of potash or soda. The solution is then to be evaporated almost to dryness, and the residue to be treated with pure alcohol, which dissolves only the urea. The alcoholic solution is afterwards to be concentrated by evaporation, and the urea is deposited in crystals.

The crystals of urea are transparent and colourless, and without odour. They leave a sensation of coldness on the tongue like nitre, and have a specific gravity greater than water. Urea is soluble in water and alcohol. Though not distinctly alkaline, it has the property of uniting with the nitric and oxalic acids. It is very highly azotized.

It is composed of

Oxygen,	26.40
Azote,	43.40
Carbon,	19.40
Hydrogen,	10.80
	100.00

The other quaternary oxides are not of sufficient importance to be here particularly described.

CHAPTER XI.

PHYSIOLOGICAL ANALYSIS OF THE ORGANIZATION.

All organized beings, vegetable as well as animal, are endued with the property of being affected by various external agents, and of being excited to action by them. All the manifestations of life in organized matter are the effect of impressions made upon it by external or internal agents, giving rise to vital reaction under the influence of this property. It is this power in the seed, the egg, and the germ, which, reacting against impressions made upon them by certain external circumstances, gives rise to a series of internal movements, by which they are gradually developed, and their organization assumes the variety, complication, and form, demanded by the type of being to which they respectively belong. This power itself assumes new properties or modifications in the different varieties of the organization thus developed; each one reacting in its own peculiar manner against the impressions made upon it; every fibre, every tissue, every organ possessing its own specific excitability, and manifesting its own

mode of activity when excited by appropriate impressions. Thus, the cellular tissue, the muscles, the nerves, the vessels, the bones, the organs of sense, enjoy each their own peculiar species of excitability according to the difference of structure and constitution bestowed upon them at their original formation. The alimentary canal is excited by the presence of food, and by its own secreted fluids. Every gland is solicited by its appropriate stimuli to secrete its peculiar product. The organs of sense are excited by certain external impressions, each in a mode peculiar to itself. The brain is roused to action by external or internal impressions, conveyed to it by means of the nerves, and the muscles are excited to contraction, by excitations derived from the nerves. In short, all the solid parts of the living system are endued with this property, and are capable of exhibiting some modification of vital reaction, under the influence of external impressions of various kinds. Even the globules contained in the blood and some of the other fluids, seem to be endued with this property; as their motions appear to be influenced by external excitations which act upon them.

The excitants which act upon the living organization, and give rise to the exercise of the functions, are of various kinds, and may be divided into two classes, external and internal.

1. *External.* The external excitants are those physical influences which are constantly or periodically applied to the system, and are indispensable to support the activity of life. These are, air, food, heat, electricity, moisture, climate, &c.

2. *Internal.* The internal are:

(*a*) The blood, and other fluids contained in the vessels and receptacles of the body, which they excite to contract, and thus to impress upon themselves incessant or periodical motion. The blood, the various secreted fluids, the chyle, the lymph, are examples.

(*b*) The solid matter of the different tissues, which act as excitants to the lymphatic and absorbent vessels, the result of which is, the disintegration of the organs, and the conversion of the solid matter of the body into a fluid state, which is necessary to facilitate its removal from the system.

(*c*) The functions of the organs, which are reciprocally excitants to one another. So intimate is the association of the numerous organs of which the human system is composed, and so closely are their respective functions connected together, that the actions of every organ are excitants more or less directly to all the others. This intimate connexion and mutual subordination of all parts of the system constitute the complex unity of life; and it is the source of that universal sympathy which pervades all parts of the organization, and which causes a single impression, made on any part of the system, to resound, as it were,

in diversified tones from the innumerable cords of this many-stringed harp.

(*d*) The immaterial stimulus of the soul, acting either consciously and with determinate aim, or blindly and without the cognizance of the individual. Thus, the stimulus of the will acting upon the brain, excites the contraction of the voluntary muscles; and the passions and emotions influence unconsciously the actions of the heart and blood-vessels, and also excite fibrous contractions of many other organs of involuntary motion. Thus they influence many of the secretions, as the biliary, urinary, cutaneous, intestinal, and lachrymal.

The excitability of the system is of different kinds, corresponding with the diversified nature of the excitants which act upon it.

1. That which responds to the impression of external agents, is found in the great surfaces of the body, exposed to external influences. Thus the skin is excited by the influence of air, temperature, and moisture; the lungs by the atmosphere; the stomach by food.

2. The excitability which is acted upon by internal excitants is:

(*a*) That of the heart and blood-vessels responding to the stimulus of the blood.

(*b*) That of the internal surfaces of other canals and cavities answering to the stimulus of their respective contents. This kind of excitability is exemplified in the secretory and excretory vessels, and in the receptacles of various secreted fluids.

(*c*) Excitability of the lymphatics answering to the stimulus of the molecules of the organs.

(*d*) That of the organs in respect to the stimulus of function of other organs. This in the physiological state is the source of normal, and in the pathological, of morbid sympathy.

(*e*) The excitability of the muscles, which responds to the stimulus of the will, or rather to that of the nervous power set in motion by the will; and that of the fibrous structure of the involuntary muscles, as the heart, stomach, and secretory organs, to the immaterial stimulus of the passions.

(*f*) The excitability of the brain to the immaterial stimulus of the soul, and

(*g*) That of the nerves to the stimulus of the brain and to other excitants which act upon them, viz. impressions of various kinds from external and internal causes, which, when made upon the nerves, give rise to sensation, open or latent, or some other mode of nervous re-action.

This property of living matter assumes three principal modifications in the different solids and fluids, and may be analyzed into three distinct forces, viz. *sensitive*, *motive*, and *alterative*. The sensitive powers are *sensibility*, and its modifications; the

motive, are *contractility* and *expansibility* or *erectility;* the alterative may be comprehended under the expression, *vital affinity.* These may be termed the physiological properties of the organization, which distinguish it in a peculiar manner from lifeless matter. In addition to these, living matter possesses certain *physical* properties in common with inanimate bodies, as *elasticity, extensibility, flexibility, imbibition,* and *evaporation.*

I. *Physiological* or *vital* properties.

1. The first of the physiological properties is *sensibility,* which is the exclusive attribute of the nervous system. It is peculiar to animals provided with nerves, and its office is to enable them to receive from the external world, or from their own organization, impressions of which they are conscious.

Sensibility presides over all our sensations, external and internal, and may be divided into two kinds, viz. *general* and *special.*

General sensibility animates the whole periphery of the body, the skin, and the origin of the mucous membranes. In the interior of the body, it exists in all the soft solids, and its office appears to be, to convey to the mind a knowledge of the wants of the system; and, in a pathological state, to apprise it by means of the sensation of pain, of the disorders which exist in the organization.

Special sensibility is a property which is the basis of the relation existing between the organs of specific sensation and the peculiar stimulants which act upon them. Thus the eye is endued with specific sensibility to light; the ear to impressions of sound; the palate to tastes; &c.

Sensibility, both general and special, has a common centre, which is the *brain.* This organ is the great focus of sensation, to which all impressions must be transmitted before they can be felt. Its own action is indispensable to sensation; for, if it be rendered by any cause incapable of reacting upon the impressions transmitted to it from the senses, no sensation is excited by them. It is here, also, that sensation, elaborated by the intellect, gives rise, directly or indirectly, to all the modes of perception and thought.

According to Bichat and some other physiologists, there is another species of sensibility, which does not require the intervention of the brain, and which has received the name of *organic.* It resides in the organs where it is called into exercise, and its centre is supposed to be the *great solar plexus.* Its manifestations are independent of the brain, never, at least in the normal state, invoking the assistance of this organ, nor giving rise to the feeling of consciousness. According to Bichat, the stomach may be said to be sensible to the presence of food; the heart to the stimulus of the blood; the excretory vessels to the presence of their respective contents, &c.; but in all these cases, which are

examples of *organic* sensibility, the feeling is either confined to the organ where it is excited, or it perhaps extends to the great ganglionic centre. It is not prapagated to the brain, and is not accompanied with the consciousness of the individual.

It is evident, however, that the existence of this species of sensibility stands on very different grounds from those on which the former rests. We have the highest possible evidence of the existence of cerebral sensibility, in our own feelings and consciousness; whereas that of organic sensibility is a mere hypothesis which we are induced to make, to enable us to explain certain phenomena which appear to imply it.

If, however, we admit of the existence of this species of sensibility, we may divide the faculty into two kinds, viz. *cerebral*, and *organic* or *vegetative*. The first has a common centre, the *brain*, the intervention of which is indispensable to its manifestations, and its exercise is necessarily accompanied with consciousness. The second, also, has a common centre, viz. the *solar plexus*, is independent of the brain, and its exercise conveys no notice to the mind.

Cerebral sensibility is displayed in all our sensations and perceptions, external and internal; *organic* or *vegetative*, in the processes of digestion, circulation, secretion, absorption, nutrition, &c.

In some parts of the system, according to Bichat, the presence of those fluids or solids with which these parts are usually in contact, produces only organic impressions, which, in a healthy state, never give rise to animal sensation. This is the case with the mucous membranes lining passages which open to the external air. The presence of the fluids secreted by these membranes, and the transit of the substances to which they are designed to give passage, in general excite little sensation of which we are conscious. The impressions which these substances produce, are confined to the surface with which they are in contact. But if foreign bodies be brought into contact with them, cerebral sensation is immediately developed, and the individual becomes conscious of the impression. There are also certain parts of the body, which in a healthy state appear to be wholly destitute of *cerebral* sensibility, though their growth and nutrition, in common with that of other parts of the system, prove that they possess *organic*. These are the bones, cartilages, and ligaments, parts which are wholly destitute of feeling in a healthy state. But when they are affected with disease, animal sensibility is sometimes developed in them, and they become the seats of acute pain. The alimentary canal possesses cerebral sensibility at its two extremities, but organic in the intermediate parts.

The peculiar seats of cerebral sensibility, are the organs of animal life, or of *relation*, as they are termed; as the skin, and the organs of sense, the nerves, muscles, and, in a less degree,

the membranes and viscera. All the solid parts, without exception, are endued with organic sensibility, for all parts are nourished and grow.

Sensation, or nervous reaction, differs from all others in not being accompanied with motion of ponderable matter. All the other actions of the economy, are performed by the agency of some kind of appreciable motion, as muscular contraction in all its varieties, respiration, circulation of the blood, digestion of food, secretion, absorption, nutrition. All these processes are attended with a change of place of masses of matter, either fluid or solid, or with molecular changes implying motion, though not always perceptible to the senses.

Nervous reaction, on the other hand, is accompanied with motion of imponderable matter. When an impression is made upon an organ of sense, the brain instantly perceives it, and the effect implies a transfer of the impression to the brain by means of some kind of motion, analogous, probably, to that of the electric fluid. And the acts of the will which excite muscular motion by means of the nerves, produce the effect apparently by the instantaneous passage of imponderable matter from the brain to the organs which are excited to action.

This imponderable agency of the nerves is, by some physiologists, supposed in all cases to precede and to be introductory to the visible motions of matter, with which the vital functions are accompanied. Since nervous matter is every where present in the solid parts of the body, it is evident that all impressions made upon the organs, whether external or internal, are immediately received by nerves, when it is supposed they receive a certain degree of assimilation before they act upon the organs themselves. They are thus undoubtedly modified in some degree, and digested as it were by the nervous system, and brought to a condition more homogeneous to the system and to each other, and in this state of assimilation they act upon the organs; so that, however different in their nature, they are all reduced in their influence upon the organs to an imponderable agency, homogeneous to the spirit of life. They are brought much nearer in their nature to the properties on which they are to act; and the effect of these assimilated impressions, or the results to which they lead, are either physical motion of masses of animal matter, solid or fluid, as muscles, blood, &c., or it is chemico-vital motion of the molecules of matter, resulting in those changes of combination of which most of the vital functions consist.

As the stomach and lungs therefore digest food, and assimilate it to the nature of the economy, so the nervous system may be said to digest certain powers or properties of matter, when applied to, and acting upon the system, and the result of these two digestions, is respectively the invisible and imponderable

agency of the nervous power, and the *blood*—the two grand factors of all vital action.

2. *Contractility*, or the faculty by virtue of which a living part contracts, is the principal *motive* force of the system. All the motions of the body have been sometimes traced up to this property, though there appears to exist a peculiar motive power in the system, which displays itself in the dilatation or *erection* of parts, and which cannot without difficulty be referred to contractility. Broussais, however, has attempted to trace up, not only all the manifold movements of the system, but even all vital manifestations whatever, to this single property of contractility.

Living animal matter has the faculty of condensing itself under the influence of certain external impressions. In a single fibre, this condensation manifests itself in a shortening of the fibre, or the approximation of its two extremities.

This tendency to contraction exists in various degrees in different kinds of animal matter. The organic element which possesses it in the most eminent degree is fibrin. Hence those tissues which possess the greatest degree of contractility, contain the largest proportion of this principle. Accordingly, the muscles which are peculiarly distinguished by their power of contraction, are composed almost wholly of fibrin. It is, perhaps, owing to this property that the fibrin, which is maintained in a fluid state in the blood when moving in the living vessels, becomes coagulated and condensed as soon as the blood ceases to move. In the living state, the molecules of fibrin are kept in a state of mutual repulsion, perhaps by the vital influence of the walls of the vessels in which they move. But as soon as they are withdrawn from this influence, either by the death of the vessels, or by the removal of the blood from the body, the particles of fibrin approach one another by virtue of this property of attraction, and unite together into a concrete mass.

When organized into muscles, fibrin contracts on the application of certain stimuli, either transmitted by nerves from the brain, or applied directly to them.

Those tissues which are formed chiefly out of gelatin or albumen, and are wholly destitute of fibrin, as the membranes, vessels, cartilages, &c., possess a certain kind of contractility, i. e. they have the faculty of reacting against any distending force, and of recovering their former dimensions when this is removed; but they have not been supposed to be contractile in the same sense as the fibrinous tissues, i. e. to possess the power of contracting on the application of stimuli; an opinion, however, which is not strictly correct.

Vital contractility exists in two modifications.

One of them requires for its exercise the influence of the brain, which is transmitted by means of nerves to the organs in which

it is called into action, viz. the locomotive and vocal muscles. All the voluntary motions of the body, and all the muscular exertions employed in the various acts which we consciously perform, are examples of the exercise of this power. The mechanical movements of respiration, those subservient to the voice and to speech, with all the numerous gestures and motions of the body, have their foundation in this power. Its exercise is under the immediate control of the will, and is attended with the consciousness of the individual. It may be termed *cerebral* contractility, because the influence of the brain is necessary, in the normal state, to excite it to action.

The absence of cerebral contractility in a part naturally possessed of it, is called paralysis; its morbid excess or exaltation, spasm or convulsion. By Bichat this power is denominated *animal contractility;* by some others, *locomotility.*

The second modification of contractility is termed *organic,* because it is a property which belongs to, and animates every part of the organization. It is independent of the brain, and its manifestations result from the immediate excitation of the organs themselves, from stimuli applied directly to them. Its exercise is wholly uninfluenced by the will, and is not accompanied with consciousness.

Organic contractility has been subdivided into two kinds, *sensible* and *insensible,* according as its phenomena are manifest, or obscure and latent.

Thus, certain organs, as the heart, the stomach, the bladder, and the uterus, possess an inherent power wholly independent of the brain or will, of contracting in a manifest and obvious manner under certain circumstances, i. e. the application or presence of peculiar stimuli. The effect is wholly independent of the will and consciousness of the individual. Aliments excite contraction of the stomach and bowels; the presence of urine stimulates the bladder to contract; the full grown fœtus excites the uterus; the stimulus of the blood the heart, &c.

This species of organic contractility is a prominent attribute of the hollow muscles, or those which are placed out of the jurisdiction of the brain, as the heart, the stomach, intestines, &c.; but it is not exclusively confined to them. It exists in the reservoirs and canals belonging to some of the secreted fluids, and, according to some physiologists, in the skin and cellular membrane, tissues which are not muscular in their structure, and contain no fibrin, but consist almost wholly of gelatin.

Insensible organic contractility. This property is of the same nature as the preceding, and differs from it chiefly in the circumstance that its effects are much less conspicuous. In fact, the very admission of it as a distinct property is rather a deduction of reason, than the immediate result of observed facts. That is,

we are compelled to resort to the supposition of a force of this kind, in order to account for many of the vital phenomena, especially the motion of the blood in the capillary system of the circulation; that of the absorbed fluids in the lymphatics and lacteals; and the passage of the secreted fluids through the fine canals of the glands which prepare them. The phenomena hardly admit of an explanation, without resorting to the supposition of a power of contraction in the walls of the canals or vessels which are the seats of these phenomena. But as its effects are not of a manifest kind, like the contractions of the heart, or stomach, or bladder, it may be termed *insensible organic contractility.*

The motion of the blood in the two extremes of the circulating system, may serve as an illustration of these two kinds of organic contractility, sensible and insensible. In the larger vessels the blood is propelled by the sensible organic contractility of the heart. This force pushes it forward as far as the fine ramifications of the arterial system, termed the capillary vessels, where the action of the heart is probably little felt. The motion of the blood, however, still continues, though it is propelled by other causes than the action of the heart. It is forced on by the *insensible* contractions of these hair-like vessels themselves, until it passes into the radicles of the veins.

This insensible organic contractility exists in animals destitute of a heart or central moving power. The motions of their fluids must be maintained by a propulsive force of this kind existing in the vessels themselves. A similar force exists in the vessels of plants, and the motions of their fluids are maintained by it. In the animal body, the seats of this power are the capillary vessels of the circulation, the lymphatic system, including the lacteals, and the fine canals by which the secreted fluids pass out from the place of their formation.

These two modifications of organic contractility are regarded as, at bottom, the same, but differing in their manifestations according to the structure of the part to which they are attached. They have been ingeniously compared to the hour and minute hands on the dial of a clock, which are both moved by the same power; yet the motion of one is insensible to the eye, while that of the other is distinctly visible.* They possess one character in common, viz. that the effects which they produce, are not within the jurisdiction of the brain, and are wholly independent of the will. These effects are the result of various stimuli applied directly to the organs which are the seats of them. Thus, the blood, the aliments, the urine, put in play respectively the organic contractility of the heart, the stomach, the bladder; the

* Diction. de Medecine.

bile, the tears, the lymph, that of the excretory ducts of the liver, the lachrymal ducts, the lymphatics, &c.

Expansibility. Another of the motive forces is *expansibility*, a property, by the exercise of which a part becomes the seat of a turgescence or active dilatation. This power differs from elasticity, which is purely a physical property, in not requiring the application of an expanding force. It is directly opposed in its nature and effects to the faculty of contractility.

The property of expansibility is exemplified in the phenomena of vital turgescence in the *erectile tissues*, as the male and female organs of generation, both external and internal, which become turgid and gorged with blood, under the influence of venereal desire; and in the nipple, which is similarly affected in the act of suckling. The same property is manifested in the skin, and the subcutaneous cellular tissue. Thus the face is said to swell with pleasure, the neck to become tumid with anger, the ends of the fingers experience a degree of erection in the act of touching, and the papillæ of the tongue in tasting. In a state of inaction these papillæ are small, soft, pale, and indistinct. In a state of erection, on the contrary, they are enlarged, erect, red and turgid with blood. In fact, any of the soft solids, which are furnished with blood-vessels, may become the seat of this phenomenon. Any of them may become the focus of a fluxion of blood, if subjected to irritation. Thus, the internal membranes, as the serous, mucous, and synovial, when irritated, become turgid with blood, which accumulates in their vascular tissue. This is particularly exemplified in the gastric mucous membrane when excited by the presence of aliment; and in the serous and synovial membranes, when exposed to the air, or subjected to any kind of irritation. The glands exhibit similar phenomena under the same circumstances; and even the muscles and nerves, and other parts provided with vessels, become turgescent with blood when laid bare and subjected to irritation.

The parts which exhibit this phenomenon in the most conspicuous degree, as the organs of generation and the nipples, are composed of a tissue of blood-vessels, interlaced with numerous ramifications of nerves.

The erectile tissues are sometimes developed accidentally, or by disease. Aneurism by anastomosis is of this description. Hemorrhoidal tumours, also, sometimes present all the characters of the accidental erectile tissues.

The dilatation of the heart, which succeeds the systole of the organ, and the expansion of the iris, in the contraction of the pupil of the eye, are referred by some physiologists to this species of vital motion. During the dilatation of the heart, the organ swells up, and becomes harder, in expanding to receive or suck up, as it were, the next wave of blood from the veins.

The expansion of the iris, which produces the contraction of the pupil, is regarded as the active motion of the iris, because it is produced by the stimulus of light on the eye; whereas the contraction of the iris, by which the pupil is enlarged, is occasioned by the absence or diminished energy of the proper stimulus of the eye, and is always greatest in cases of paralysis or much debility of the organ.

The structure of the iris, however, is a subject of controversy among anatomists. According to Magendie and others, it is unquestionably muscular, and is composed of two sets of fibres, one of which is exterior and radiated, and by its action dilates the pupil; while the other, which is interior, or next the pupil, is circular, forming a sphincter, which, by its contraction, diminishes this aperture. If this be admitted, the contraction of the pupil is the effect of muscular action, and cannot be referred to the expansibility of the iris.

It has been conjectured that the act of absorption may be promoted by the exercise of this power in the absorbent vessels; their inhaling radicles thus opening to receive and suck in the fluids which they are destined to absorb. The extent and limits of this force, however, are not accurately defined.

3. The *alterative*, or *chemico-vital* powers of the living system may be comprehended under the expression, *vital affinity*. It is in these powers that the changes which take place in the composition of the solids and fluids of the living body originate. They penetrate and pervade all the organs, determine their structure and composition, and the changes to which, in common with the fluids, they are constantly subjected. The numerous transformations which the fluids and solids of the body undergo, as in chymification, chylosis, lymphosis, hæmatosis, the secretions, nutrition, calorification, and fecundation; and the preservation of a certain degree of cohesion or fluidity in the various animal solids and fluids, in spite of the counteracting influence of ordinary chemical agency, must be referred to this power of vital affinity. The formation of the organic elements of the body, also, as fibrin, albumen, gelatin, &c., are the results of the operation of the same power.

The exercise of this power of vital affinity, is confined principally to the fluids, and is manifested in the successive transformations which they undergo, from the state of crude aliment, as it is received into the system, to that of the nutritive fluids in the highest degree of assimilation. It is the most striking characteristic of this force of vital chemistry, to form compounds and aggregates, which could never be produced by chemical affinity. Under the influence of this power, the elements of animal matter are withdrawn from the jurisdiction of chemical laws, and are maintained in their peculiar states of vital combination, in the

midst of a variety of destructive forces, which are exerted in vain to subvert them. A new order of affinities seems to be developed in the elements of these combinations, by the influence of this vital force; affinities which cannot be satisfied by the common properties of matter, but which mutually saturate one another, and leave the compound in a state of indifference for all others.*

Vital affinity, however, is not confined in its operations to the productions of changes and new combinations in the fluids of the system. The solid tissues, also, are subject to its power. The various structures of which the body is composed, are formed and nourished by the influence of vital affinity. The structure of a living solid is determined by the same laws as those which fixed its chemical constitution. The various combinations and the different degrees of aggregation and cohesion of the elements which constitute the different tissues, must be determined by the chemico-vital forces which operated in combining and arranging these elements. The type of the organs, however, by which their shape, size, and relative position in the system are determined, must be referred to some other power, which was impressed upon the germ by the act of generation; a power which has received the name of the *vis formativa*, or force of formation.

As the formation and nutrition of the different organs and tissues of the body are executed under the control of *vital affinity*, and as the different modifications of vital power, with which they are respectively endued, result from their organization or vital composition, it is evident that the power of vital affinity is primitive in relation to the other vital forces, or is indirectly the parent of them all. This power, which is bestowed upon the germ by the act of generation, is excited to activity by the influence of external causes; and the movements to which it gives rise, determine the developement of the different structures of the body, their organization and their chemical composition, and, as a necessary consequence, the various modifications of vital power with which they are respectively endued.

II. The physical properties of the animal tissues are *elasticity*, *extensibility*, *flexibility*, *imbibition*, and *evaporation*.

1. The first of these, or *elasticity*, is possessed in the greatest degree by the cellular tissue and its modifications. It is a force which tends to restore parts which have been subjected to mechanical extension, to their former state, as soon as the extending cause ceases to act. The cellular tissue enters so universally into the composition of the organs and tissues, that, with the exception of the bones, they are all endued, though in different degrees, with this property. And the organs and membranes

* Diction. de Medecine.

are so disposed in the system, that they are kept in a constant state of extension. Thus the extensor and flexor muscles of the same parts counteract each other's elasticity, so that in a state of inaction they are in a condition of mutual extension. The hollow viscera and the vessels are kept in a state of distention by the volume of their contents. If the different soft solids were not maintained in this state by the rigidity of the skeleton, there would be a general shrinking and collapse of the organs, by the exertion of this elastic force. If a muscle be divided, the two parts recede from each other, leaving an interval between the two divided ends. When the hollow organs are evacuated, they contract by their elasticity, until their cavities are obliterated. The cartilages are highly elastic; and this property in the sterno-costal cartilages is one of the forces by which the movements of expiration are accomplished. The elasticity of the pulmonary tissue also contributes to the same effect. The elasticity of the intervertebral cartilages occasions a difference in the length of the vertebral column, and consequently in the height or stature of the body, at different times of day. Hence a person is usually a little taller in the morning than in the evening. The dilatation of the heart, which alternates with the systole of the organ, is ascribed by some physiologists to the exertion of its elasticity, overcome at first by the muscular contraction of the ventricles, but acting with effect as soon as the stimulus, which excited the organ to contract, is removed by the expulsion of the blood from its cavities.

The elasticity of the arterial tissues is an essential force in the circulation of the blood. This force constantly reacting upon the column of blood, which is projected into these vessels by the heart, and keeps them distended, maintains the motion of the blood in the arteries, and propels the vital fluid towards the termination of the arterial system. The contractility of the coats of the various canals which carry colourless and secreted fluids, is of a vital character, but is probably assisted by the elasticity of these tunics.

The elasticity of the animal tissues, though regarded as a mere physical property, is partly of a vital character, as appears from several facts. The contractility of the cellular tissue, e. g. is almost wholly destroyed by death. It is also excited to action by certain impressions, especially by heat and cold, in some instances by light,* and by some other stimulating agents. Moreover, it varies at different periods of life, in certain states of disease, and in short, according to a variety of circumstances which influence the state of nutrition.

* Tiedemann.

2 and 3. *Flexibility and Extensibility.* These physical powers exist in various degrees in different parts. The ligaments of the joints are endued with great flexibility, as the free motions of these parts require. They are also possessed of some degree of extensibility.

The tendons possess but little extensibility; and for an obvious reason. As they are attached to muscles, and serve to conduct the moving force exerted by these organs to the bones, it was evidently necessary that they should not yield themselves; otherwise the moving force would be partly expended or absorbed by them before its arrival at the bones.

4. *Imbibition.* Another important physical property of the animal tissues is *imbibition.*

If a liquid be placed in contact with an animal tissue, after a certain time it will be found to have penetrated into the latter, as it would into a sponge. All the soft animal tissues possess this power of imbibition. Some of the tissues absorb with great facility, as the serous membranes and the small vessels; others, as, e. g. the epidermis, are penetrated by fluids with much greater difficulty.

The phenomena of imbibition are curious; and they appear to depend both on the nature of the fluid absorbed, and the texture of the absorbing tissue.

Detrochet found, that on filling the intestine of a chicken with milk, or some other dense fluid, and plunging it into water, the milk passed out of the intestine through its coats, and the water into it, in the opposite direction; and from repeated experiments of a similar kind, he deduced the conclusion, that whenever an organized cavity containing a fluid is immersed in another fluid less dense than the former, there is a tendency in the membrane to expel the denser fluid, and to absorb the rarer. And if the contained fluid be the rarer, then the passage of the two fluids occurs in the opposite directions.

The same phenomena are exhibited by the gases. If a bladder be filled with pure hydrogen gas and exposed to atmospheric air, the hydrogen in a short time will become contaminated with atmospheric air, which penetrates through the coats of the bladder.

It appears, on the whole, that substances formed of organic matter imbibe or are penetrated by fluids of various kinds, and all kinds of gases; and that every animal and vegetable tissue is possessed of this property.

According to Chevreul, many of the animal tissues are indebted for their physical properties to the water which they imbibe and retain. If they are deprived of this water, their properties are so much changed that they are rendered unfit for

their proper offices in the animal economy; but if they are placed in contact with water, and become again impregnated with this fluid, their former properties are restored.

5. *Evaporation.* This is another physical property which the animal tissues and organs possess in common with inorganic bodies. Whenever the body or any of the organs is placed in circumstances favourable to evaporation, the aqueous part of the fluids begins to pass off in the form of vapour from the exposed surface, and the loss thus occasioned is greater or less according as the surrounding circumstances are more or less favourable to evaporation. The losses of fluid thus occasioned may be so great under some circumstances, as, in some animals, to cause speedy death.

CHAPTER XII.

THE FUNCTIONS.

By the functions are meant the vital actions. The phenomena of life consist in an assemblage of actions, forming an uninterrupted circle, in which it is impossible to find either beginning or end. Every thing is complicated in the vital functions. Every thing depends on something which precedes it; and the antecedent, in many cases, is equally dependent on that which follows. The circulation of the blood, e. g. is an effect of the motion of the heart and blood-vessels. Now the motions of these organs indispensably require the presence of blood circulating in them; that is, the circulation presupposes itself. The heart is enabled to beat and to maintain the circulation only by means of the blood which circulates in its own vessels. The heart requires the action of the lungs, and the lungs no less the action of the heart. Without the action of the lungs, an impure blood would be returned to the left side of the heart, by which its own vessels would become penetrated, and its power of contraction paralyzed; and without the action of the heart, the functions of the lungs would instantly cease, because no blood would be sent to these organs, either for their own nutrition or to be purified by respiration. The lungs are no less under the influence of the brain, and the brain dependent both upon the heart and the lungs. If the lungs be deprived of the influence of the brain, their functions are instantly suspended; respiration ceases; the dark blood brought to the lungs by the pulmonary artery is no longer purified by these organs, but is returned to the heart in

the foul state of venous blood, and thence a portion of it transmitted to the brain, which, like the heart, soon becomes paralysed by its poisonous influence. The heart, it is true, is not immediately dependent on the brain; but it is so indirectly, through the medium of the lungs. All the functions of the system, the circulation, respiration, innervation, &c., are dependent upon digestion, and digestion indispensably requires the aid of the circulating, respiratory, and nervous systems. It appears, therefore, that all the great functions of life are mutually dependent; that they form a circle, in which it is equally impossible to distinguish a beginning or a termination, and of course to determine which are primitive, and which secondary phenomena.

This mutual dependence and subordination of the functions, renders it impracticable to establish any natural order in treating of them. Begin where we will, there are antecedent phenomena, the knowledge of which is indispensable to that of those we are considering; and, consequently, every classification which can be adopted must be more or less arbitrary and defective. The arrangement which will be adopted in this work, as, on the whole, less objectionable than any other, is that of Chaussier.

Chaussier admits four classes of functions; 1, *vital;* 2, *nutritive;* 3, *sensorial;* 4, *genital.*

1. *Vital.* If we examine with attention the living system in organized beings, we perceive a class of functions, the exercise of which is absolutely indispensable, every moment, to maintain them in the living state. This first and most important class of functions may properly be termed the *vital functions,* and they are three in number, viz. *innervation, circulation,* and *respiration,* or the functions of the nervous system, those of the heart, and those of the lungs. These constitute what has been fancifully called the tripod of life; they are three great columns which support the whole fabric of the living system.

2. *Nutritive.* A second class of functions has for its object the introduction into the system of the materials of growth and nutrition, the assimilation of these to the various tissues and organs, and the expulsion from the system of heterogeneous or worn-out elements. This class embraces the four functions, *digestion, absorption, nutrition,* and *secretion.* The great object of this class of functions is to repair the waste in the organs incessantly caused by the actions of life, and to maintain them in the state of nutrition necessary to the support of these actions. They may be termed the *nutritive* functions. The exercise of them is not so immediately necessary to life as that of the first class.

3. *Sensorial.* The third class may be called the *sensorial functions,* or *functions of relation.* These comprise the sensations, intellectual operations, and the voluntary motions. They

establish the relations between living beings and the external world; and become wider in their sphere in proportion as organized beings ascend in the scale of existence. In the vegetable world they can hardly be supposed to exist at all. In the inferior animals they are limited to the narrow circle of mere physical wants: but in the human species they present their greatest developements. They confer upon man an intellectual and moral existence, and extend his relations to objects and beings which are elevated far above the sphere of his physical necessities.

These functions, of which the brain is the common centre, are susceptible of great improvement by education, and are much influenced and modified by the power of habit. They are less necessary to life than either of the two former classes, and their exercise may be suspended for a considerable time without danger.

4. *Genital.* The fourth class of functions, is the *genital.* These have no concern with the preservation of the individual, but relate solely to the perpetuation of the species. They are distinguished from the others by several peculiarities. In a majority of organized beings, they require the concurrence of two individuals, or at least of two distinct organic apparatuses, one male, the other female. They are not unfolded until the individual has attained that stage of constitutional developement termed puberty; and in the human race, and some of the superior animals, they cease in the female at a certain epoch of life.

CHAPTER XIII.

FIRST CLASS, OR THE VITAL FUNCTIONS.

Innervation.

By the term innervation is meant the physiological action of the nervous system.

The nervous system is an integral part of the animal organization, the functions of which are in the highest degree important and interesting; but of the precise nature and extent of these, much difference of opinion exists among physiologists.

One great office of the nervous system, about which there is no dispute, is to preside over the sensorial functions, or those of relation; that is, the sensations, and the voluntary motions. But

besides this, it exercises an influence over the functions of organic or vegetative life, the degree and extent of which, however, is not well defined, and is a subject of much controversy among physiologists. It is to this influence of the nervous system upon organic life in general, that the term *innervation* is, in strictness, applied; while that which it exercises over the two primary organs of this department, viz. the lungs and the heart, assigns to innervation a place among the vital functions, or those indispensably necessary to life. As presiding over sensation and voluntary motion, the functions of the nervous system fall under the third class, or those of relation.

The nervous system is divided into two great sections, which may be termed the ENCEPHALIC, and the GANGLIONIC; the former of which is sometimes called the nervous system of *animal*, the latter, that of *organic* life.

Encephalic Nervous System.

The *encephalic* nervous system consists of the *encephalon*, and the conductors of sensation and of motion, called *nerves*.

By the *encephalon* is meant the medullary mass contained in the cranium, and its prolongation, the vertebral canal. It is formed of four parts, viz. the *cerebrum*, the *cerebellum*, the *annular protuberance*, and the *spinal marrow*. The *cerebrum*, *cerebellum*, and *pons Varolii*, are termed collectively the *brain*, that globular mass of nervous matter which fills the cavity of the cranium. The greatest length of this organ is about six inches; its transverse and vertical dimensions, about five inches each. Its weight in the adult is between three and four pounds.

1. *Cerebrum.* The *cerebrum* in man, constitutes much the most considerable part of the encephalon. The upper surface of it, which is convex, is divided longitudinally by a deep fissure into two equal and symmetrical halves, termed hemispheres, which are separated by a fold of the *dura mater*, called the *falx*. The fissure which separates the two hemispheres, is bounded inferiorly by a kind of bridge of medullary matter, called the *corpus callosum*, which reunites the two hemispheres of the brain below.

The whole periphery of the *cerebrum* is intersected by deep fissures, and presents numerous winding eminences, termed convolutions, which exhibit a striking resemblance to a mass of intestines. The fissures between the convolutions are from twelve to fifteen lines deep, and, according to Gall, they result from the packing or folding up of the membrane of which he supposes the brain to consist. The depth of these fissures is said to bear some ratio to the developement of the intellectual powers.

The inferior surface of the brain is divided into three distinct regions on each side, termed lobes. The anterior and middle lobes are separated by a transverse depression called the *fissura Sylvii.*

In the substance of the brain are found four cavities, termed *ventricles.* Two of these are called *lateral ventricles,* one of which is situated in the central part of each hemisphere. They are irregular in their shape, and each has three winding prolongations, which are termed *cornua.* The anterior cornua are separated by a transparent membranous partition, called the *septum lucidum,* composed of two laminæ, the separation of which leaves a small cavity between them, called the *fossa Sylvii,* or the fifth ventricle. The two lateral ventricles communicate with each other by an opening, called the *foramen of Monro.*

In the lateral ventricles several parts are found, for a particular description of which, we must refer to books on anatomy. Among them are the *fornix,* which is a flat body of a triangular shape, supporting the *septum lucidum,* having its upper surface contiguous to the *corpus callosum,* and its lower resting upon the *choroid plexus,* and the *optic thalami;* the *corpora striata,* which are two smooth eminences, situated in the anterior part of the lateral ventricles, and, on being cut into obliquely, exhibiting a striated appearance, owing to alternate streaks of grayish and whitish matter; the *optic thalami,* two oval eminences, lying between the diverging extremities of the corpora striata, and their upper surface, forming a part of the floor of the ventricles; the *commissura mollis,* a band of cineritious matter, which connects the convex surfaces of the optic thalami; the *tænia semicircularis,* a line of white matter running between the convex surfaces of the optic thalami, and the corpora striata; the *plexus choroides,* situated under the fornix, consisting of a plexus of tortuous vessels, covering the optic thalami, and the corpora striata, and extending into the inferior *cornua* of the lateral ventricles. This plexus returns its blood, by two veins, called *venæ Galeni,* which run backward and enter the *sinus rectus.* Between the optic thalami and the crura cerebri, is a deep fissure, which communicates with the lateral ventricles by a small aperture at its upper and fore part. This is called the *third ventricle.*

2. The *cerebellum* or little brain, is, next to the latter, the most voluminous part of the encephalon. In the adult, its weight is about one-eighth or ninth part of that of the cerebrum. It is situated under the posterior lobes of the cerebrum, from which it is separated by the *tentorium.* Like the brain, it is divided into two lateral halves by the lesser falx, and it is composed of two hemispheres united behind by the vermiform processes which rest upon the *medulla oblongata,* and before by the *pons Varolii.* On its upper surface, it presents five fasciculated lobules, common

to both lobes, and disposed in transverse concentric bands. The inferior part of the cerebellum presents a convex surface, on which may be distinguished four lobules disposed in concentric arches. When a section is made between the two hemispheres a beautiful arborescent appearance presents itself, formed by the peculiar arrangement of the white and gray matter of the brain, which is termed *arbor vitæ.* In the cerebellum exists a cavity called the *fourth ventricle.* The third and fourth ventricles communicate with each other by an opening, termed the *aqueduct of Sylvius.*

3. The *annular protuberance,* or *pons Varolii,* is a large round eminence situated between the cerebrum and the cerebellum, and apparently formed by the union of processes from them, termed the *crura cerebri,* and *crura cerebelli.* The posterior surface of the pons Varolii presents, on its upper part, four tubercles, termed the *tubercula quadrigemina.* The two superior, which are larger and more prominent than the inferior, are termed the *nates;* the two others, the *testes.* The *pineal gland* corresponds to the point of intersection of the two grooves which separate the tubercles.

4. The *medulla spinalis,* or spinal marrow is a cylindrical cord of nervous matter, which originates from the pons Varolii, passes downwards through the occipital foramen, and extends through the vertebral canal as far as the first vertebra of the loins, where it terminates; forming with the other parts of the encephalon, what is sometimes termed the cerebro-spinal axis. That part of it which extends from the pons Varolii to the occipital hole, is termed the *medulla oblongata.* On its surface it presents four eminences, termed the *corpora pyramidalia,* and the *corpora olivaria.* The two former are oblong bundles of medullary matter lying contiguous to each other; and on the outside of these are the two others, which, from some resemblance in shape to olives, are called corpora olivaria.

The posterior surface of the medulla oblongata is contiguous with the pons Varolii, and contributes to form the fourth ventricle. On each side of the upper and back part of the medulla oblongata, are situated two oblong eminences termed the *corpora restiformia.*

The remaining part of the *medulla spinalis* is a long cylindrical cord, occupying the vertebral canal, and extending from the occipital foramen to about the level of the first lumbar vertebra. On its anterior surface, a deep fissure extends through its whole length, dividing it into two equal lateral parts. Its posterior surface, also, is divided by a median groove.

The spinal cord is considered by some anatomists as consisting of four columns, two ascending to the cerebrum, and two descending from the cerebellum; by others as consisting of two

only. According to Bellingeri, it consists, throughout its whole course, of six whitish or medullary strands; viz. two anterior, two lateral, and two posterior. The two anterior are separated from each other by the anterior median furrow, and from the lateral strands by the anterior horns of the gray matter. The posterior strands are separated from each other by the posterior median furrow, and from the lateral strands either by the posterior horns of the gray matter, or by the posterior collateral furrows.

The anterior strands are continuous with the corpora pyramidalia, and the *crura* of the brain, and may be termed the *cerebral* strands of the cord. The lateral columns are continuous with the corpora restiformia, and may be denominated the *restiform* strands. And the posterior columns communicate directly with the cerebellum, and may be termed the *cerebellic* strands.

The vertebral cord, instead of exhibiting the appearance of a regular cylinder, presents two remarkable enlargements, one of which extends from the second cervical nerve to the first dorsal; the second is comprised between the first lumbar and the third sacral nerve. The first of these is larger than the second, and the volume of each of them appears to be in the direct ratio with the developements of the corresponding upper and lower extremities. This relation exists in the fœtal state, and continues after birth, and according to Serres, the bulbs of the spinal cord, as well as the limbs which correspond with them, progressively increase until the age of thirty years; and on the approach of old age they begin to diminish, and this diminution is accompanied with an atrophy of the upper and lower extremities.

The substance of the encephalon presents two distinct kinds of matter, one termed the cortical or cineritious, the other, the medullary or white. The first constitutes the external part of the brain, covering the subjacent matter to the depth of about one-sixth of an inch, and entering deep between the convolutions. It is of a grayish colour, and of a firmer consistence than the medullary matter. The cortical substance is essentially vascular, and perhaps is designed to protect the brain from the impulse of the blood, by dividing the vessels sent to it into infinitely small twigs. It also serves, perhaps, to nourish the medullary part.

The medullary or white matter is situated interiorly. It constitutes much the larger portion of the whole mass of the brain, and is traversed by a great number of ramifications of blood-vessels. The mass of the brain seems to be formed of an expansion of the fasciculi of medullary fibres of the medulla oblongata, and especially to originate from the corpora pyramidalia and olivaria. The fibres of the former from each side decussate each other, and contribute to the formation of the opposite part of the brain. Besides this lateral decussation of the brain, there

exists, according to some physiologists, an antero-posterior one; since the effects of a lesion of the corpora striata are said to be manifested in the legs, and those of an injury of the optic thalami, in the arms.

The brain is subject to several motions. During sleep it is said to become less turgid, and to suffer a degree of collapse; but on waking, it rises again, and fills more completely the cavity of the cranium. The difference depends on the different degrees of activity of the brain, in these two states of the system. Another motion depends on respiration. The brain rises during expiration, but sinks in the act of inspiration. A third depends on the pulsations of the heart, with which it synchronizes. During the systole of the heart, the blood is propelled forcibly into the arteries of the brain, and communicates a pulsatory motion to the organ, which sinks again during the diastole of the heart. The spinal marrow is subject to similar motions.

These motions of the brain are said to be a prerogative of the higher classes of animals, the *mammalia;* for they are not observed either in birds, reptiles, or fishes.

The brain receives its blood by the vertebral arteries and the two internal carotids; the principal branches of which occupy the base of the brain. Numerous veins ramify over the surface of the organ, and terminate in osseo-fibrous canals, which open into the jugular veins. The quantity of blood which it receives, is very great, amounting, it is supposed, to one-eighth of the whole quantity which issues from the heart.

Chemical Analysis of the Brain.

The analysis of the substance of the brain, exhibits the following results:

Water,	8.000
Albumen,	700
White fatty matter,	453
Red do. do.	70
Osmazome,	112
Phosphorus,	150
Sulphur,	515
Traces of phosphates of potash, lime, and magnesia, and muriate of soda.	
	10.000

Envelopes of the Brain and Spinal Marrow.

The encephalon is contained in a large, roundish case, formed of bones, and prolonged inferiorly into a cylindrical canal. The globular case is termed the *cranium,* and its prolongation, the *spine.* The cranium is formed of eight bones, viz. the *frontal,*

the *ethmoid*, the *sphenoid*, the *occipital*, the two *parietal*, and the two *temporal* bones; and it contains the cerebrum, the cerebellum, the pons Varolii, and the medulla oblongata. The spine is a column, composed of twenty-four perforated bones, called vertebræ, piled one upon another, in such a manner as to form a continuous canal, and distinguished into three kinds, according to their position in the column; viz. seven *cervical*, twelve *dorsal*, and five *lumbar*. It is terminated by two other bones, the *os sacrum*, and the *os coccygis*, and it contains the vertebral part of the spinal cord.

Within its bony case, the encephalon is enveloped by three membranes, viz. an external, termed the *dura mater*, a middle, called the *arachnoides*, and an internal, or the *pia mater*.

1. The *dura mater* is the external envelope of the brain. It is a strong fibrous membrane, which forms the internal periosteum of the cranium, adhering loosely to the bones of the skull, except at the sutures and foramina. By maceration it is divisible into two or more laminæ.

Its internal surface forms several folds or duplicatures. One of these constitutes the *falx cerebri*, which separates the two hemispheres of the brain from each other. Its upper edge, extending from the frontal ridge to the middle groove of the occipital bone, contains the superior longitudinal sinus. Its lower edge, which passes over the corpus callosum, contains the inferior longitudinal sinus.

Another process of the dura mater, is the *tentorium cerebelli*, which is a membranous partition, separating the cerebrum from the cerebellum. Its outer circumference contains the lateral *sinuses*.

The *falx cerebelli* is another process of the *dura mater*, which lies between the lobes of the *cerebellum*. These different partitions appear designed to maintain the principal divisions of the encephalon in their respective situations, and to prevent them from being compressed by one another. In animals, whose habits of life lead them to spring down from elevated places, as the cat, there are bony partitions between the principal parts of the encephalon, instead of the membranous folds of the dura mater.

2. The *arachnoides* is situated between the dura mater and pia mater. It is a serous membrane, and consequently forms a closed sac. It is expanded over the convolutions of the brain without dipping into the fissures which separate them, and over the cerebellum, and the base of the pons Varolii. It forms a sheath for all the nerves and all the vessels which pass into, or out of, the cranium. It also passes downwards into the vertebral canal, envelopes the spinal marrow, and gives a sheath to each of the vertebral nerves. This membrane penetrates into the third

ventricle by a small opening between the corpus callosum, and the tubercula quadrigemina; it lines the third ventricle, and is continued over the parietes of the lateral and the fourth ventricles, into which it penetrates through the *aqueduct of Sylvius.*

3. The *pia mater* is the third membrane of the encephalon. It is a loose cellulo-vascular membrane, which immediately invests the brain, dipping into the fissures which separate the convolutions, and covering the superior surface of the corpus callosum; enveloping, inferiorly, the base of the brain, the pons Varolii, and the surface of the cerebellum. It penetrates into the third and lateral ventricles, where it forms the *choroid web*, and the *plexus choroides.* It appears to be a delicate tissue of blood-vessels, connected and supported by soft cellular membrane.

The pia mater, which invests the spinal marrow, is connected to the *arachnoid* membrane by a loose cellular tissue and by blood-vessels; leaving, however, an interval between the two membranes, which is filled by a liquid. This space communicates with the ventricles of the brain by means of the fourth ventricle. The fluid, which thus surrounds the spinal marrow, it is conjectured, may serve the purpose of blunting the shocks or concussions accidentally impressed upon the spine, and thus of preserving the cord from mechanical injury. According to Ollivier, a spinal fluid also exists between the two laminæ of the arachnoides itself. Magendie informs us that the spinal fluid exists in all the mammiferous animals as well as man, and at every period of life, occupying the whole length of the vertebral canal.

The *encephalic* nerves constitute the second part of the encephalic system. These nerves are white cords, extending from the brain or spinal marrow to every part of the system, and are the conductors of sensitive and motive impressions. They are disposed in symmetrical pairs, and are composed of filaments, connected together by cellular tissue.

Of these nerves there are forty-three pairs. Two pairs originate from the cerebrum; viz. the *olfactory,* and the *optic.* Five pairs from the pons Varolii and its peduncles, viz. the *motores oculorum,* or third pair; the *pathetici,* or fourth pair; the *trifacial,* or fifth pair; the *external motory nerves of the eye,* or sixth pair; and the *facial* nerve, or seventh pair.

The remaining thirty-six pairs originate from the spinal marrow; viz. five from the medulla oblongata; viz. the *auditory* nerve or eighth pair; the *glosso-pharyngeal,* or ninth pair; the *pneumogastric,* or tenth pair, sometimes called the eighth pair, and the *par vagum;* the *hypoglossal;* and the *spinal accessory.* Eight arise from the *cervical* part of the spinal marrow; twelve from the *dorsal;* five from the *lumbar;* and six from the *sacral.*

All these nerves furnish numerous filaments, some of which

pass directly to the organs to which they are destined, and which, for the most part are the senses and the muscles of voluntary motion; others form numerous anastomoses between the encephalic and the ganglionic nervous systems; and a third class are employed in the formation of *plexuses*, which consist of a network of filaments proceeding from different branches, interlaced together.

The plexuses formed by the encephalic nerves, are four in number; the *cervical, brachial, lumbo-abdominal,* and *sacral.*

1. The *cervical* plexus is formed by the anterior branches of the second, third, and fourth cervical nerves, is situated in the lateral part of the neck on a level with the second, third, and fou th vertebræ, and gives rise to four principal nerves, which are distributed to the head, neck, and the superior parts of the thorax.

2. The *brachial* plexus is formed by the anterior branches of the four last *cervical*, and the first *dorsal* nerves. It lies concealed, in a great measure, in the cavity of the axilla, and gives rise to eight principal branches, distributed to the thorax, shoulder, and arm.

3. The *lumbo-abdominal* plexus is formed by the anterior branches of the five lumbar nerves, lies behind the psoas muscle, and gives origin to six principal nerves, the five first of which are distributed to the parietes of the pelvic cavity, and most of the organs contained in it; and the last, termed the lumbo-sacral nerve, descends into the pelvis, and unites with the sciatic or sacral plexus.

4. The *sacral plexus* is formed by the anterior branches of the four first sacral nerves, occupies the sides of the pelvic face of the *sacrum*, and gives off three principal branches, the two first of which are distributed to the cavity of the pelvis, and the viscera contained in it, and the third, an immense nerve termed the *sciatic*, is distributed to the lower limbs.

Ganglionic Nervous System.

The second grand section of the nervous system is called the *ganglionic*, and sometimes the nervous system of organic life.

By *ganglions* are meant small bodies of a grayish white colour, of a roundish, or elongated shape, varying in volume from the size of a hemp-seed to that of an almond; most of them extending in a series along the sides of the vertebral column, from the base of the cranium to the superior extremity of the coccyx, and connected together by nervous filaments.

Each ganglion transmits nerves both upwards and downwards to the ganglions nearest it, and others to anastomose with the cerebro-spinal nerves. Some of them furnish branches, which

are distributed immediately to certain organs, as to the arterial coats, or to particular viscera. Thus, the *ophthalmic ganglion* gives origin to the *ciliary* nerves; the *submaxillary*, to the filaments which supply the salivary glands; the *spheno-palatine*, the *cavernous*, and the *naso-palatine*, to branches which are distributed to the arteries and neighbouring parts, &c. But most of the filaments proceeding from the ganglia, are destined to the formation of the numerous plexuses belonging to this system. Thus the cervical ganglions supply filaments, which form the three cardiac nerves, superior, middle, and inferior, which terminate in the cardiac plexus. The thoracic ganglions, from the fifth to the eighth or ninth, inclusive, send off filaments which contribute to the formation of the great splanchnic nerve; and the tenth and eleventh furnish branches which form the little splanchnic nerve.

The ganglions are numerous, and are found in different situations. Most of them extend in a series along the vertebral column; six are found in the head, and several in the abdomen.

The ganglions, which exist in the head, are the *ophthalmic*, the *spheno-palatine*, the *cavernous*, the *naso-palatine*, the *submaxillary*, and the *otic*, or the ganglion of Arnold. Of those which lie along the vertebral column, three, or sometimes only two, are found in the neck, and are called the *cervical* ganglions; eleven or twelve, in the *dorsal* region; five, four, or sometimes only three, in the *lumbar;* and three in the *sacral*.

In the abdomen, are found the great *semilunar* ganglions, situated on each side of the aorta, on a level with the cœliac artery. By their superior extremity, these ganglions receive the great splanchnic nerves, and by their inferior, they communicate with each other. A number of smaller ganglia surround the two semilunar, and are connected with them by anastomosing filaments. This collection of ganglia and nervous filaments interlaced together, constitutes the *solar plexus*.

Plexuses formed by the ganglionic nerves. The nervous branches furnished by the ganglions, unite in a great number of points with branches of the encephalic nerves, forming inextricable plexuses. From these originate numerous branches, some of which are distributed to the neighbouring organs, but much the larger portion to the coats of the arteries, which they accompany in their principal divisions, forming secondary plexuses.

The principal of these plexuses are the following, viz:

The *cardiac* plexus, formed by the three nerves of the same name. From this plexus branches arise, which form the *coronary* plexus:

The *pulmonary* plexus, formed by filaments of the pneumogastric nerve, and the anterior branches of the first thoracic ganglions:

The *solar* plexus, formed by the great and little splanchnic nerves, and by numerous branches furnished by the semilunar ganglion and its accessories. From this great centre spring branches which serve to form a great number of secondary plexuses, as the *diaphragmatic* plexus; the *cœliac*, from which originate the *coronary* of the stomach, the *hepatic*, and the *splenic*; the *superior* and *inferior mesenteric*, the *renal*, whence is formed the *spermatic*, &c.

The ganglionic system is termed collectively, the great sympathetic nerve. It seems to arise from the sixth cerebral nerve, and from the vidian branch of the fifth. It receives filaments from the seventh, eighth, and ninth, and all the spinal nerves, to the lumbar region, and extends to the pelvis, where it terminates.

Functions of the Nervous System.

The functions of the nervous system may be divided into two general classes; the first, those of *relation*, comprehending the sensations, voluntary motions, and the intellectual operations; the second, those by which it influences the other functions of the system, as the respiration, circulation, digestion, nutrition, secretion, calorification, &c.

The first class of these functions does not, in strict propriety, fall under consideration at present, because it constitutes the third general class into which the functions of the system are distributed, viz. the *sensorial*, or those of relation. It is the second class, viz. those by which the nervous system controls, or influences the other functions most necessary to life, particularly respiration, and the circulation, which finds a place among the vital functions; though it is proper to state, that several distinguished physiologists have embraced the opinion, that innervation is the first and most indispensable condition of life; that it constitutes the very essence of vitality; is common to all organized beings, without exception, and is essential to every manifestation of life.

In treating of the functions of the nervous system, we shall consider separately the different parts of which it is composed, viz. the brain, spinal marrow, and nerves.

I. The *brain*, comprehending the *cerebrum*, *cerebellum*, and *pons Varolii*, may be considered as the great centre of this section of the nervous system, and one of the most important organs in the whole animal economy. It is the great developement of the brain in the human race, which raises man so far above all other animals, even those, which from their near approach to man in external shape and internal organization, are termed anthropomorphous. The functions over which the brain presides, are the sensations, the voluntary motions, and the intellectual and moral

faculties. It is the seat of consciousness, and of the feeling of individuality, the temple in which is enshrined the perceptive, thinking, and willing principle. The spinal marrow and nerves are subordinate organs, whose office it is to transmit impressions from the organs of sense to the brain, and the cerebral influence in the contrary direction, to the muscles of locomotion and voice. Besides these, which are the sensorial functions of the brain, it exercises an important influence over many of the other functions of the system, particularly *respiration*, and the *circulation*, as has been already observed. These two classes of the cerebral functions, though differing essentially from each other, I shall not separate, but consider together; while, under the third class of the functions, or those of relation, will be considered the senses, and the subject of voluntary motion.

1. *The sensorial functions of the brain*. These include sensation, voluntary motion, and the intellectual and moral faculties.

Sensation. The organs of sense and the nerves are the immediate seats of sensation, but its ultimate seat is the brain. Every sensation we experience, from whatever cause it originates, and by whatever channel it is introduced, requires the intervention of the brain before it can be felt. The impression itself is made upon some organ or sensible part, more or less remote from the brain; but before sensation can be excited by it, the impression must be conveyed to the brain, and in some way or other modified, or digested, as it were, by this organ. Of this the proof is perfectly conclusive. If the nerve, which connects an organ of sense with the brain, be divided or compressed, no sensation will be excited in the mind by impressions made upon the organ. The same physical effect will be produced as before by the external agent; but the channel between the organ of sense and the brain being obstructed, the impression is no longer conveyed to this great focus of sensation, and no feeling, consequently, is excited. A circumstance truly curious in this process of sensation is, that, though the brain is the ultimate and real seat of sensation, yet every sensation is always referred to the organ of sense on which the impression that gives rise to it is made; so that there would appear to be a double organic action in all cases of sensation, viz. one from the organ of sense to the brain, by which sensation is excited; the other from the brain towards the organ, by means of which it is referred to the latter.

The agency of the brain in sensation is strikingly illustrated by those curious cases of delusive sensation, which sometimes occur in persons who have lost some of their limbs, and who complain of pain or some other sensation in a part which no longer exists. Here the brain is evidently the only seat of the sensation; and this is as real as if the part to which it is referred, actually existed. For the essence of a sensation consists in

being felt. When it is felt, it exists; when it is not felt, it does not exist. These sensations are delusive only in being referred by the mind to a part which has no existence; but this only proves that the reference itself is a cerebral action, and may be exerted even in the absence of the organ, to which the reference is made.

In certain diseases or injuries of the brain, by which the organ is rendered incapable of exerting its usual powers, impressions upon the organs of sense excite no sensation in the mind. The organs of sensation which are the recipients of the impressions, and the nerves proceeding from them to the brain are uninjured; but no sensation is excited, because the brain is unable to react upon, and to digest the impressions received from them. In such circumstances, as a person receives no sensations from any of his senses, external or internal, he is in a state of general insensibility. A similar torpor of the brain may be produced by the action of opium, alcohol, and other narcotics; and, accordingly, we find that persons completely under the influence of these agents, are in a great measure insensible to external impressions.

There is another state of the system in which the action of the brain is suspended, while this organ, as well as the organs of sense and the nerves retain their integrity, but in which, impressions made upon the senses, excite no sensation in the mind. This state is sleep. In this periodical inaction of the brain, the senses partake, because they derive their power of being excited by external impressions, from their connexion with this organ. No impression upon the senses is noticed or excites consciousness, merely because the brain, in a state of repose, is incapable of receiving them, and of reacting upon them. If, however, these impressions, whether made by external causes, or produced by affections of the organs themselves, are of a certain degree of strength, they may so far excite the action of the brain, as to give rise to an imperfect sort of sensation, or to that shadowy kind of consciousness which we term dreaming.

On the other hand, the activity of the brain may be so absorbed by its own peculiar functions, as profound meditation, or exclusive attention to some engrossing subject of thought, that impressions upon the senses are not perceived, because the cerebral power is already fully occupied, and none can be spared to give audience to these messages from the senses.

In the cases enumerated above, sensation is not excited, because the brain does not react upon the impressions transmitted from the senses. It might be conjectured from this, that if the action of the brain directed to these impressions, could in any way be increased, the sensations excited by them would become more vivid than under the ordinary degree of cerebral reaction. Now the fact is found strictly to accord with theory in this case.

We have the power of increasing the activity of the brain, by an effort of the will, or by an energetic concentration of the attention upon the impressions received from the senses; and when we exert this power, we find that the increased cerebral energy adds strength and distinctness to the resulting sensations. Slight impressions, and such as, perhaps, would scarcely have been perceived under the circumstances, which are constantly distracting and dissipating the cerebral energy, become distinct and even vivid sensations, when the scattered rays of the mind are recalled, concentrated together in a focus, and thrown directly upon them. The action of the brain is, therefore, as essential an element of sensation, as the impressions made upon the organs of sense.

One further proof that the brain is the ultimate organ of sensation, may be noticed in this place. In certain affections of the brain, sensations are sometimes excited by the mere action of the brain itself, without the corresponding impressions upon the senses. We have examples of this curious fact in certain nervous diseases, as catalepsy, hypochondriasis, and mania. Insane persons sometimes listen attentively to fancied strains of celestial music, to which they earnestly call the attention of others. In the same manner, the tales of visions and apparitions, which have been so frequently told, and so generally discredited by all but the ignorant and the superstitious, admit of an explanation in perfect consistency with physiological principles. The brain has been highly excited by the operation of fear and awe, upon ardent imaginations. The action of the brain has naturally corresponded with the state of feeling which gave rise to it, and has, accordingly, been such as the actual impression of some fearful object upon the senses, would naturally have produced in the brain; and according to the law which operates in all cases of actual sensation, it has been accompanied by a reference to the appropriate organ of sense. The shape under which the hallucination will be embodied in such cases, will probably be determined by accidental circumstances, and the habitual or prevailing associations of the individual.

It is remarkable, that though the brain is the ultimate seat of sensation, yet both the cerebrum, and cerebellum themselves are destitute of sensibility. Wounds of these parts, as it seems to be established by experiments, do not excite pain. The whole of the hemispheres has been pared away, the cerebellum removed in the same manner, the corpora striata, and the optic thalami cut away, and yet the animal subjected to this shocking experiment, remained perfectly passive, exhibiting no indications by cries or struggles, that it was suffering pain. But as soon as the operator reached the tubercula quadrigemina, trembling and convulsions immediately took place. The medulla oblongata, and spinalis are highly sensible. According to Magendie, sensi-

bility exists in an exquisite degree in the spinal marrow, particularly on its posterior surface; while on the anterior it is much more feeble. Very acute sensibility also exists in the sides of the fourth ventricle; but this property diminishes in approaching the anterior part of the medulla oblongata, and becomes very feeble in the tubercula quadrigemina.

Voluntary motion. The brain is also the organ of the will, the point of departure of all our voluntary motions. The immediate instruments of motion are the muscles. It is by the contraction or shortening of these, that motions are impressed upon the moving parts of animal bodies. The muscles possess a peculiar power of contracting, upon the application of certain stimulants. Thus, mechanical irritation applied to muscular fibres, excites them to contract; and without the application of some stimulant power, the contractility of the muscles remains in a dormant state, and the organ does not contract. Now the stimulus which acts upon the voluntary muscles, so as to excite their faculty of shortening themselves to exert itself, is the influence of the brain, set in motion by an act of the will. No voluntary action can be performed without the agency of the brain. Of the mechanism of these actions we are totally ignorant. We are conscious only of the two extremes of the phenomena, the act of the will, which is an immaterial agent, and which by an internal sentiment we refer to the brain, and the physical effect to which it leads, viz. the motion we will to produce; and, notwithstanding the distance which separates the two places where the cause operates, and where the effect is produced, we are not conscious of any interval of time between the two phenomena. The energy of the brain is conveyed, as if by electricity, to the instruments of motion, which are instantly excited to their appropriate actions.

The cerebral influence, however, may be set in motion by other causes besides the will, and contractions of the voluntary muscles be excited not only without the agency of volition, but even in spite of the strongest efforts of this faculty to prevent them. Thus, any irritation applied to the brain, or developed in it by disease, will frequently excite involuntary contractions of the muscles, which usually act only under the will. Irritations, also, seated in other parts of the body, as the alimentary canal, may excite the brain sympathetically, and determine the cerebral influence to the muscles of voluntary motion, giving rise to those involuntary contractions, which are called convulsions or spasms. In such cases a person may retain his consciousness, and the power of the will may exist in full vigour; and yet, it is wholly unable to restrain the contractions of the muscles excited by the influence of a more powerful stimulus. The physical stimulus of the brain is more energetic than the immaterial, and the organ

acted upon, by two opposite forces, yields to that whose action is most powerful.

The proofs that the brain is the seat of the will, the source of voluntary action, are of the same kind and equally conclusive with those that it is the organ of sensation. If the communication between the brain and any organ of voluntary motion be cut off, by dividing, compressing, or stupifying by opium, the nerve which forms this communication, no act of the will can excite to motion the part so isolated from the brain. In these cases the brain is as capable as ever of exerting its powers of volition; but the acts of the will can no longer influence the muscle to contract, because the channel of communication between the two organs is no longer open. Certain diseases of the brain, or injuries inflicted upon the organ, abolish the power of volition. It is remarkable, that in these cases, the same cause which destroys the faculty of the will, and of course prevents voluntary contractions of the muscles, may act as a physical or morbid irritation to the brain, and give rise to spasmodic or involuntary contractions of them.

The disease termed paralysis, affords another illustration of the dependence of voluntary motion upon the brain. In this disease, some of the voluntary muscles lose their power of contracting under the influence of the will. The brain still retains its power of exerting an act of the will, but is unable to give effect to the act by exciting the paralysed muscles to contraction. This condition in hemiplegia, and some other varieties of palsy, is generally connected with some lesion of the brain, which may be the effect of disease or of accident. It does not so far impair the power of the brain, as to abolish the faculty of volition; but it destroys the physical influence of the acts of this faculty upon the organ, so that the nervous energy is not transmitted to the affected muscles, which consequently are not excited to contraction. It would seem probable, from this fact, that the faculty of volition has a distinct seat in the brain, and that its physical influence is exerted upon some other part of the organ, whence it is transmitted to the conductors of the cerebral energy, the nerves. If the seat of the faculty itself be materially injured, no act of the will can be exerted. But if the seat of the injury be any part of the brain, on which the will is exerted, or through which it must be transmitted, in its passage to the muscles of voluntary motion, then though an act of the faculty may be exerted by the individual, yet no corresponding contraction of the voluntary muscles will follow it.

During sleep, in which the brain is in a state of inaction, and the faculty of volition dormant, there is no contraction of the voluntary muscles. A person asleep, if placed on his feet, is unable to support himself in an erect position, but obeys the law

of gravitation, and sinks to the ground. If sleep overtakes him while sitting, its first approaches are indicated by nodding of the head forward; because the strong muscles of the back of the neck are no longer able to support it; and not being poised exactly on its centre of gravity, but resting on the vertebral column behind this centre, its anterior part preponderates.

Intellectual and moral faculties. The brain is the organ of the intellectual and moral faculties. The proofs of this are of an incontrovertible kind. The connexion of the brain with the operations of the intellect, and of the moral faculty, is shown by numerous facts. An internal sentiment leads us irresistibly to refer the acts of the mind and of the moral faculty, to the brain or head. No one ever imagined that he carried on his reasoning operations in his lungs, stomach, or liver. These organs, like all others, have certain functions peculiar to themselves. The same is true of the brain. A healthy state of certain parts of this organ is necessary to the exerise of the rational and moral powers; and accordingly we find that injuries of the head, frequently destroy or impair the faculties of the mind. The same consequences result from certain diseases of the brain, a fact which is remarkably exemplified in apoplexy, and in insanity—two diseases which are, probably in all cases, connected with some physical change in the state of the brain. In general, in all cases of *acute* disease, in which the patient preserves his mental faculties unclouded to the last, we may be pretty certain that the brain is unaffected; and, on the other hand, whenever we find him become drowsy, stupid, or insensible, we may be equally sure, that this organ has suffered some physical change, which, in most cases, will be apparent on dissection. Opium, alcohol, and other narcotics, which exert so striking an influence upon the mental faculties, owe this property to their power of producing certain changes in the brain.

Like all the other organs of the body, the brain experiences the effects of the exercise of its functions, in an increase of its volume. If the intellectual powers are duly cultivated, the organ acquires its full developement and growth; if they are neglected it probably never attains the expansion of which it is capable. This circumstance is important; for it explains the fact, that the neglect of early intellectual culture, in many cases, can never be compensated by subsequent education. The brain, in these cases, has not been sufficiently developed in its organization and volume, by necessary exercise. It is incapable of acting with the energy of a fully developed brain, and no voluntary efforts of the individual can overcome the obstacle; for it is a physical one, connected with the state of the organization. On the other hand, severe exercise imposed upon the brain in its tender state, in young children, is still more pernicious; for it prematurely ex-

hausts the energy of the organ, and brings on its early decrepitude. The brain at first, under the influence of artificial excitements, is rapidly unfolded, the intellectual faculties soon bud and blossom, every thing gives hopes of an early and abundant harvest, but the fruit never ripens, but falls half-formed to the ground.

Localization of the Cerebral Functions.

Numerous experimental researches have been made in order to determine the functions which respectively belong to different parts of the brain; but as yet, without very satisfactory results.

The *cerebral lobes* are supposed to be the seats of the faculties of thinking, memory, and the will; and according to some physiologists, ultimately, of all the sensations.

Vertical pressure upon the hemispheres of the brain, occasions stupor,—an effect, however, which Mayo ascribes to the compression of the medulla oblongata. Lateral pressure is said to be followed by no sensible effect.

The lobes of the brain appear to be that portion of the organ in which all the sensations assume a distinct shape, and leave durable traces in the memory; a property, by which they furnish the materials of knowledge and judgment.

The ablation of one of the cerebral lobes, or a profound lesion of it, is followed by blindness of the *opposite* eye, and by a paralytic weakness of the muscles of the *opposite* side of the body.

If both lobes are removed, much injured, or compressed, according to Flourens, there is from that moment neither sight, hearing, smell, taste, memory, thought, nor will. The animal subjected to the operation, sinks into an apoplectic stupor; a fact from which Flourens infers, that the cerebral lobes constitute the organ of the memory, of the will, and, ultimately, of all the sensations. It is a curious fact, that although the sight of the opposite eye is destroyed when one of the cerebral lobes is removed, the contractility of the iris remains unimpaired. If the conjunctiva, the optic nerve, or the tubercula quadrigemina, be irritated, the iris contracts with convulsive force; a fact, from which it appears, that while the principle of vision resides in the cerebral lobes, that of the contractility of the iris exists elsewhere.

Magendie, on the contrary, asserts that neither the cerebrum, nor the cerebellum, is the principal seat of sensibility, or of the special senses. He affirms that if the lobes of the cerebrum, and those of the cerebellum, be removed in one of the mammalia, the animal still remains sensible to strong odours, to sounds, and to tastes. He admits that vision is abolished by the ablation of the cerebral lobes; but this fact he accounts for by observing, that vision does not consist in the simple perception of light; but

that the action of the apparatus of vision, is almost always connected with an intellectual or instinctive operation, by which we form ideas of the distance, size, shape, and motion of objects; and this intellectual element of vision, he supposes, requires the intervention of the cerebral hemispheres.

On this subject Magendie remarks, that the sense of vision has a threefold seat in the brain; viz. the cerebral lobes in the sense just explained, the optic thalami and the fifth pair of nerves. An injury of one of the thalami is followed by a loss of sight in the *opposite* eye, and a section of the fifth pair occasions blindness of the eye on the *same side.* Hence it appears that the influence of the hemispheres and of the optic thalami upon vision, is transverse or exerted upon the opposite sides, while that of the fifth pair is direct.

Admitting, however, that the cerebral lobes are the seats of memory, of the will, and of the sense of vision, it is certain that these faculties may continue unimpaired, when the lobes of the brain are mutilated or wounded. Even deep wounds of the brain are not invariably followed by debility of sensation or motion, or of the mental faculties; facts, which render it probable, that a portion of these lobes, perhaps the central part, may suffice for the exercise of these functions. In some cases, a lesion of one hemisphere will give rise to disorder of the intellectual faculties; in others, intelligence continues unimpaired. In the first case, the intellect sometimes halts, as it were, in consequence of the two hemispheres acting unequally. By the unimpaired action of the sound one, the patient seems to be conscious of the crippled state of the other. He understands perfectly well the questions addressed to him, and perhaps meditates a rational answer; but when he attempts to express himself, he talks nonsense, or says something entirely different from what he intended, and perhaps, conscious of the incoherence and absurdity of his words, he stops and endeavours to recollect himself, and makes another attempt with the same success. In such cases the two hemispheres do not, and cannot act in harmony. The powers of intelligence appear to rally to the sound hemisphere, leaving to the crippled one the inferior office of giving expression to its thoughts.

An extensive lesion of both hemispheres, it is supposed, can scarcely exist without materially impairing the intellectual powers. Yet I have known extensive disorganization of the brain in the form of numerous large tubercles, the largest of which equalled a small pullet's egg in size, interspersed throughout the brain and cerebellum, yet accompanied during the whole course of the disease with uncommon clearness and even acuteness of mind. The patient was a young girl of very great promise. The disease was of three years' standing at the time

of her death, which occurred at the age of nine. It was accompanied with complete amaurosis for the two last years of her life, and with paralysis of both lower extremities. During this time, her appetite was good, she grew fast, and her intellect was unclouded.

The office of the *cerebellum* is supposed to be, to regulate and combine different motions to a determinate object. A wound of one side of the cerebellum is followed by a weakness of the same side of the animal. If the wound be deep, the body on the injured side becomes paralytic.

Serres however affirms, that lesions of one of the lobes of the cerebellum occasion paralysis of the limbs on the *opposite* side. If the lesion of the cerebellum is on the left, the paralysis affects the right side, and *vice versâ*. Of the truth of this opinion he adduces several proofs from pathology, and experimental physiology. The division of the one side of the cerebellum he found to produce a flexure of the body towards the same side, in consequence of the muscles of the opposite side being no longer able to counterbalance those of the other. The disposition to turn in the same direction, seems to proceed from the greater strength of the muscles on the side corresponding with that of the lesion. The animal is evidently weaker on the opposite side, seeks to be supported, and is apt to fall on the same side.

In the experiments of Flourens, wounds and injuries of the cerebellum were found to cause a discord, or want of harmony, rather than a weakness, of the voluntary motions. The ablation of it occasioned a loss of the power of combining the motions, necessary to the mode of progressing which is proper to the species of the animal, subjected to the experiment. The animal appears to be intoxicated, and exhibits a singular propensity to go backwards. Another remarkable phenomenon is a kind of rotation or whirling round, which is said to be sometimes exhibited by persons, after wounds, or in diseases, of the cerebellum. Sometimes patients affected with diseases of this organ, whirl round in their beds in a very extraordinary manner. Further, if a vertical incission be made into one side of the cerebellum, the animal rolls over and over, always turning itself towards the injured side; at the same time a want of harmony is observed in the direction of the eyes, one of them being turned upwards and backwards, the other, downwards and forwards. On making a similar incision in the opposite hemisphere parallel to the first, the motion of the animal ceases, and the harmony of direction in the two eyes is immediately restored.

Magendie observed that the same effect was produced by dividing the *crus cerebelli* in a rabbit, as by dividing the cerebellum unequally. The animal survived the experiment eight days; and during the whole time it continued to revolve upon its

long axis, except when arrested by some obstacle. The division of the opposite *crus* put a stop to the motion.

If a section of the cerebellum on one side gave rise to a constant revolution towards the same side, the division of the opposite *crus cerebelli* did not restore the equilibrium, but the animal began to revolve towards the side of the divided *crus*.

These curious phenomena Mayo ascribes to a sensation like vertigo, produced by the lesions of the cerebellum.

Upon comparing the cerebrum and the cerebellum together, in relation to the effect of injuries upon them, it appears that lesions of the cerebellum give rise to a want of harmony in the voluntary motions; those of the cerebrum, implicate the senses, understanding, and will. Compression of the brain produces the effect of opium; alterations of the cerebellum, the effects of the abuse of alcohol. In the former case there are symptoms of narcotism; in the latter those of intoxication. Lesions of the cerebrum produce paralysis or immobility; those of the cerebellum, agitation and disordered motions, and especially a disposition to go backwards, and a rotation of the body. Diseases of the cerebrum destroy the harmony of ideas; those of the cerebellum, the harmony of motions. The cerebellum influences chiefly the lower limbs; the cerebrum, the upper.*

The *tubercula quadrigemina* have been supposed chiefly to influence the voluntary motions of the body, the sense of vision, and the contraction of the iris. The removal of one of these, weakens the sight, and the motions of the iris of the *opposite* eye, causing dilatation of the pupil. The total destruction of the tubercles produces blindness, immobility of the iris, and dilatation of the pupils. Serres, however, states that he has seen these bodies disorganized, but had never witnessed in these cases, a loss of vision. Irritation applied to the tubercles occasions convulsions and contractions of the iris. Magendie, however, remarks, that he had never seen that an injury of the optic tubercle affected the vision in the mammiferous animals, though this effect was very evident in birds.

The destruction of the *pons Varolii*, occasions immobility of the body, and the loss of all the senses. The respiration and circulation are not affected, unless the injury extends to the medulla oblongata.

Artificial irritation of the pons on one side, causes contraction of the pupil of the same side, but convulsions of the opposite side of the body. General irritation applied to it, produces contraction of the pupils, general convulsions, or universal paralysis, paralysis of the muscles of inspiration, and vomiting.

Inflammation of the pons causes rigidity of all the limbs, and

* Bourdon.

permanent contraction of the pupils. If it is inflamed more on one side than the other, the contraction of the pupil is greater on the same side, and the rigidity of the limbs on the opposite. Sometimes there is trismus.

According to Bourdon, the pons Varolii is situated between the functions of the will and those of instinct, exactly on the limits of intelligence and life. Above it, all is voluntary; below it, all is spontaneous and automatic.

The *optic thalami* are believed by some physiologists, to influence the motions of the arms, and the *corpora striata*, those of the lower extremities; so that lesions of the former, it is supposed, may occasion paralysis of the arms, and those of the latter, paraplegia or palsy of the lower extremities.

Paralyses of the arms are said to be more obstinate than those of the legs, because the lesions of the optic thalami are generally the profounder and more durable. Further, as the thalami are nearer the medulla oblongata, morbid affections of them more frequently affect respiration. Hence paralysis or convulsions of the arms, are oftener accompanied with oppressed respiration than those of the legs.

According to Bourdon, paraplegia is often accompanied with, or preceded by, a pain in the temples; a fact which is explained by the anterior situation of the corpora striata.

The *optic thalami*, also, like the *tubercula quadrigemina*, are subservient to the sense of vision, and the *corpora striata* to that of smell. So that the same parts of the brain which are instrumental in vision, are subservient to the sense of touch, in regulating the motions of the arm; and the organs of locomotion are allied to the sense of smell by means of the corpora striata, which are subservient to both.

According to Serres, it is only a certain part of the optic thalami which is instrumental in vision. He says that he has seen the whole superior surface destroyed without impairing this sense, and even if the injury penetrates deeper, vision is not lost, unless it reaches as far as the level of the *commissura mollis*, which he regards as the boundary of the sense.

In these affections, vision, instead of being destroyed or impaired, sometimes becomes double; and what is still more remarkable, in some cases the patients see objects double with one eye, and single with the other; and cases have occurred, in which the double vision in one eye has become single, and in the other the reverse.

The optic thalami, and the corpora striata, according to Serres, exercise a special influence upon the voice, speech, and articulation.

The parts of the encephalon which seem to be particularly destined to motion, are the corpora striata, the optic thalami, in

their inferior part, the crura cerebri, the pons Varolii, the peduncles of the cerebellum, the lateral parts of the medulla oblongata, and the anterior part of the spinal marrow. And according to Serres, it is established by facts, that the medulla oblongata and the pons Varolii exert an equal influence over the motions of the limbs; that the lobes of the cerebellum have a greater influence over the lower than the superior extremities; while, on the contrary, the cerebral lobes influence the superior more than the inferior limbs.

It may be proper here to mention the opinions of a celebrated Italian physiologist, Bellingeri, respecting some of the functions of the different parts of the brain. Bellingeri endeavours to prove that the cerebral lobes, the anterior strands of the spinal cord, and the anterior roots of the spinal nerves, are subservient to motion; and that the cerebellum, the posterior strands of the spinal cord, and the posterior roots of the spinal nerves, also preside over motions. In proof of the first proposition, he refers to numerous authorities to show, that while injuries and diseases of the superior part of the brain affect chiefly the intellectual faculties, lesions of the middle lobes and corpora striata affect principally the motions of the abdominal or sacral extremities; and that injuries and diseases of the optic chambers, and posterior lobes of the brain, affect chiefly the motions of the thoracic extremities. He also adduces experimental proof of the subservience of the anterior strands of the spinal cord, and the anterior roots of the spinal nerves, to the motions of the limbs. In proof of the subservience of the cerebellum, &c. to motion, he adduces the experiments of various physiologists, which show that sections of the cerebellum produce paralysis of the muscles of the *opposite* side. He also refers to numerous cases in which morbid states of the cerebellum gave rise to tetanic rigidity of the muscles, trismus, rigid tension of the extremities, general convulsive motions, and priapism; and others, in which palsy of various muscles was produced by diseases of the cerebellum.

Bellingeri, further endeavours to prove that the lobes of the brain are subservient to the motions of *flexion;* and the cerebellum, to those of *extension.*

In proof of the first position, he adduces various experiments of different physiologists, as Magendie, Flourens, &c. Thus, Serres found that the removal or injury of one of the *anterior* lobes of the brain, was followed by *flexion* of the opposite *abdominal* extremity; and the removal of both anterior lobes produced the flexion of both abdominal extremities. On the contrary, the division or removal of the *posterior* lobes of the brain is followed by *flexion* of the *thoracic* extremities. The removal or destruction of the hemispheres of the brain, causes an irresistible motion of progression forwards; while wounds or

destruction of the cerebellum produce a retrogressive motion. From pathological investigations, Bellingeri infers that inflammation or any irritation of the cerebral lobes produces spasm, which assumes the form of flexion, and sometimes, also, of adduction of the extremities; from which he infers that the cerebral lobes preside over the motions of flexion and adduction of the extremities. In proof of the proposition that the *cerebellum* presides over the motions of *extension*, he adduces various experiments from different physiologists; the general result of which is, that irritations excited in the cerebellum induce *opisthotonos*, or spasmodic extension of the head, trunk, and posterior extremities; that in some instances of lesions inflicted on the cerebellum, these spasmodic motions may be so violent as to throw the animal completely backwards; and, that the motion of retrogression observed by Magendie in injuries or irritations of the cerebellum, is owing to the spasmodic action thus induced in the extensor muscles, by which the animals are compelled involuntarily to move backwards. In support of the same position, Bellingeri adduces a variety of pathological facts.*

2. *Influence of the brain over the organic functions.* The influence of the brain over the organic functions is comparatively inconsiderable, being far inferior to that of the spinal marrow. Most of the great functions of the system, however, appear to be more or less influenced by cerebral innervation; as respiration, the circulation, digestion, secretion, nutrition, calorification, &c.

Thus *respiration* is, in some degree, subject to the influence of the brain, because the external muscles of respiration belong to the class of the voluntary muscles, which derive their nervous influence directly or indirectly from the brain. The internal sentiment of the want of respiration, which produces the cerebral reaction upon the external muscles of respiration, must be referred to the seat of consciousness in the encephalon, wherever this may be. This internal sentiment, however, is by no means necessary to respiration; for this function goes on without intermission when consciousness is suspended, as e. g. during sleep, and in certain cerebral diseases. And where the latter are accompanied with stertorous or embarrassed respiration, the effect is to be ascribed to compression or lesion of the medulla oblongata. The action of the brain, therefore, is not necessary to respiration; and accordingly we find that the removal of the whole organ does not destroy this function, provided that the medulla oblongata be left uninjured. Acephalous infants have lived some days after birth. In an account of an acephalous child by Mr. Lawrence, it is stated that the brain and the cra-

* Edinb. Med. and Surg. Journ. No. cxx.

nium were deficient, and the basis of the latter was covered by the common integuments, except over the foramen magnum, where there existed a soft tumour about the size of the end of the thumb. This child lived four days, and *breathed naturally,* and was not observed to be deficient in warmth until its powers declined. The medulla spinalis was found to extend about an inch above the foramen magnum, swelling out into a small bulb, which formed the soft tumour upon the basis of the skull. All the nerves, from the fifth to the ninth, were connected with this. The most extensive organic disease may exist in different parts of the brain without affecting respiration. Yet, that this function is influenced by the brain, appears from the fact, that certain emotions of the mind produce an evident effect on the movements of respiration.

The *action of the heart,* also, is considerably influenced by the brain. It is well known that violent emotions, and all strong moral affections powerfully influence the action of the heart. A sudden emotion of surprise frequently occasions palpitation. A vivid sensation of joy has, in many instances, occasioned sudden death, by paralysing the heart. It is related of the painter Francia, that he was struck with such admiration by a painting of Raphael, that he swooned and expired on the spot. The passion of fear, also, produces a strong depressing effect upon the circulation. Terror has, in some instances, caused a mortal syncope; and aneurisms of the heart have been often produced by this cause. According to Desault, the Reign of Terror in France, in the year 1793, was uncommonly fruitful in this disease. Diseases and injuries of the brain, also affect the circulation. Compression of this organ from extravasated blood, or effused serum, in many cases renders the pulse preternaturally slow, or irregular. In these examples, it is true, respiration is frequently much disordered, and the affection of the circulation may be considered as an indirect and secondary effect. But there are cases of morbid affection of the brain, which point out a more immediate action of this organ upon the heart. For example, I have known symptoms of cerebral disease which seemed to threaten hydrocephalus, but from which the patient recovered, accompanied with an intermittent or irregular pulse, which continued during the whole course of the affection. Concussion of the brain, also, is attended with great depression of the action of the heart, and of the capillary circulation, together with coldness of the surface. The well known power of digitalis in causing a slow or intermitting pulse, is probably connected with its sedative influence upon the brain. Though it is true that the injection of an infusion of this plant into the veins, produces the same effect, partly perhaps from its direct action on the heart.

The removal of the brain, according to Dr. Phillip and others,

does not diminish the action of the heart; but if it be suddenly destroyed, as by crushing it, the motion of this organ is immediately enfeebled.

Digestion, also, is influenced in some degree by the brain, as appears by the effects upon the function, produced by certain mental emotions. The effect produced by the division of the pneumogastric nerves upon digestion, is to be ascribed to the interception, not of the influence of the brain, but of that of the medulla oblongata.

With respect to the other organic functions, which for the most part are exercised in the parenchyma of the organs, and the capillary vessels, and which derive their powers principally from the ganglionic system, the influence of the brain may be inferred from the disturbance occasioned in these functions by moral causes, such as violent passions, or emotions. These causes take their rise in the brain, and the effects which they produce in modifying the organic functions, are illustrative of the influence of cerebral innervation over the department of vegetative life. The passions affect the capillary circulation and calorification; for the skin becomes red or pale, and hot or cold, under the influence of certain passions.

The *secretions,* also, manifest the influence of cerebral innervation. Grief increases the secretion of tears; fear, that of the kidneys. A cold sweat sometimes starts out from the skin under the influence of the same moral cause. The peculiar state of the nervous system which exists in hysterical affections, frequently occasions a copious secretion of pale urine, but sometimes produces the opposite effect, and suppresses the secretion. A fit of anger has been known to change the qualities of the milk, so as to give rise to colic and diarrhœa in infants nourished by it. Boerhaave relates a case of this kind, in which epilepsy was excited by this cause, and continued to return during the whole life of the patient.

The cerebral influence, also affects *absorption,* and probably *nutrition* likewise. It is well known, that persons under the influence of fear are peculiarly liable to be attacked by contagious, or epidemic disease; while those who are calm and fearless in the general panic, are much less liable to suffer. This fact renders it probable that the passion of fear promotes absorption, as some other debilitating causes undoubtedly do; and that the morbific principle, whatever it be, is thus more easily introduced into the system of persons affected by it. The paralysis of a limb often tends to atrophy or withering; a fact which appears to evince the influence of encephalic innervation upon nutrition. Paralytic parts also sometimes swell or become œdematous.

These facts, and numerous others of a similar kind, appear to leave no doubt, that the parenchyma of the organs, as well as

the capillary system, are supplied with nerves, which subject them, in some degree, to the influence of the brain.

The brain is also believed, by many physiologists, to be the instrument of that mysterious vital relation, which exists between, and connects together, the different organs; in other words, it is supposed to be the principal agent of the sympathies.

On the whole, the brain is the organ of intelligence; it directs the means by which we react upon the external world; it exercises an important influence over the functions of internal life; and, as the great centre of the nervous system, is probably the principal organ of sympathy.

These functions of the brain, especially the two latter, render this organ indispensable to life in the higher classes of animals; and accordingly we find that injuries of this organ from accident or disease, are generally, though not invariably, fatal.

Though it be true, however, that the functions of internal life are more or less influenced by cerebral innervation, yet it must not be inferred that they are dependent on this organ; since it is well known that full grown fœtuses have been born, destitute of every trace of a brain, and even of a spinal marrow. From this, it should seem, that during fœtal life the innervation of the ganglionic system is sufficient to maintain the nutritive and vital functions, in their imperfect and rudimentary state; but that after birth, when the individual commences a new and more elevated existence, when all the phenomena of animal or external life start at once into existence, and the brain, their common centre, is roused to the exertion of all its sleeping energies; when two of the most important of the organic functions which are immediately dependent on encephalic innervation, viz. digestion and respiration, first begin their exercise; the empire of the brain is extended over all the functions of life, connecting them together in a bond of reciprocal dependence and sympathy; and cerebral innervation then becomes indispensable to their regular exercise, and consequently to animal life. A curious conclusion to which Hall has been led by his experimental researches is, that this process of nervous developement may, in some of the lower orders of animals be reversed, as it were, by the successive removal of portions of the nervous system. He remarks, that if such a part of the nervous masses be removed as can be spared without the immediate destruction of life, the animal is reduced to a lower degree in the scale of organized beings. It lives, but degraded below the level to which it properly belongs, and it acquires an increased power of enduring further mutilations. In this manner, Hall believes the whole brain and spinal marrow might be removed, and the animal live, supported by the ganglionic nervous system, and cutaneous respiration.

Functions of the Spinal Cord.

The influence which this part of the nervous system exercises upon some of the most important functions, places it in the first rank of organs most necessary to life. The spinal marrow is found in all the higher classes of animals, under different forms, and the more highly developed, in proportion as their whole organization is more perfect. By its direct communication with the brain on the one hand, and on the other with the different parts of the body, it becomes the principal channel of communication between the common centre of sensation and voluntary motion, and the immediate instruments of these functions, viz. all the sensible parts of the trunk and limbs, and the muscles of voluntary motion. It exercises, also, an important influence over many of the organic functions, particularly respiration, calorification, cutaneous transpiration, the digestive functions, and the motions of the heart.

In treating of the functions of the spinal cord, I shall consider first, its sensorial functions; secondly, those by which it influences the vital and organic ones.

I. *Sensorial functions.* According to Mayo, it appears from Magendie's experiment of removing the cerebrum, optic tubercles, and cerebellum in a living animal, that the brain may be taken away by successive portions, and yet the animal survive, and exhibit sensation and instinct. But if the mutilation be carried a line further, so as to comprise that small segment of the medulla oblongata, in which the fifth and eighth nerves originate, consciousness is at once instantly extinguished. From this experiment it would seem to follow, that this portion of the medulla oblongata, instead of the cerebral lobes, is the seat of consciousness. Mayo remarks, further, that the rest of the nervous system derives its vitality, or rather its participation in the phenomena of consciousness, from its continuity with this small portion of the medulla oblongata. In proof of which, he states that in cold-blooded animals, as the frog or turtle, consciousness will continue some time after the head has been severed from the body; and it will remain either in the head or the body, according as the section of the medulla oblongata has been made *below* or *above* the spot just described. If the section be made below this vital part, the body is deprived of sensibility while the head continues to exhibit marks of consciousness. But if the section be made just above the origin of the fifth and eighth nerves, the result is directly opposite; for the head is deprived of life, while the body remains alive. According to Mayo, the stupor occasioned by vertical pressure upon the hemispheres of the brain, is owing to the compression of the medulla oblongata. The same author observes in connexion with this subject, that when vomiting has

been excited by an emetic, it is arrested by pressure applied to the medulla oblongata.

The spinal marrow may be regarded as a common centre of the nerves, distributed to the muscles of voluntary motion, and of those subservient to general sensibility. It is not, however, independent of the brain. It is only a conductor, and perhaps we may say a prime conductor, of sensific impressions from the limbs and trunk of the body to the brain in one direction; and of motive impulses from the seat and source of volition, the cerebral lobes, to the muscles of voluntary motion in the other.

It has been known from the infancy of medicine, that injuries of the spinal marrow occasion a paralysis, both of sensation and motion, of the parts situated below the injured portion of the cord. A division of the cord in any part of its course, always paralyses the limbs, and that portion of the trunk of the body situated *below* the seat of the injury, leaving the parts *above*, wholly unaffected. If the injury occur high up in the neck, it causes almost instant death. The involuntary discharge of urine and fæcal matter, which is frequently the consequence of injuries of the spine, was referred by Galen to a paralysis of the nervous filaments which are distributed upon the sphincters of the bladder and rectum. It is also well known, that irritations applied to the spinal marrow, excite convulsions of the trunk and limbs below the seat of the irritation.

The researches of Bell, Magendie, and others, appear also to have established the fact, that the anterior part of the spinal cord presides over voluntary motion, and the posterior over sensation. The spinal nerves originate by double roots, one anterior, the other posterior; and Magendie found that dividing the posterior roots of the spinal nerves, which supplied one of the hind legs, completely destroyed the sensibility of the limb, without affecting its power of motion; and, on the other hand, that the section of the anterior roots abolished the muscular power, without impairing the sensibility of the limb. A striking evidence of the same fact is furnished by the *nux vomica*, a poison, which, in some animals, excites the most violent spasms, but which produces no such effect, if the anterior roots of the spinal nerves be previously divided.

It appears, however, that the isolation of these two properties in the anterior and posterior roots of the spinal nerves, is not complete. If an irritation be applied to the posterior roots, contractions are produced in the muscles to which the nerves are distributed, though they are much less violent than when the anterior roots are irritated. In like manner, slight indications of sensibility are observed, when an irritation is applied exclusively to the anterior roots.

The isolation of these two properties, sensibility and motility,

from each other, in the double roots of the spinal nerves, will enable us to account for those cases of paralysis, in which the loss of power is confined exclusively to the sensibility or the motility of the paralysed part.

The gray central part of the spinal cord, appears to be the principal seat of these two properties; for the roots of the spinal nerves, are found to penetrate into this central portion of the cord.

There is still, however, much difference of opinion respecting the functions of these parts of the spinal marrow. According to Bellingeri, the posterior strands preside over the movements of extension, and the anterior over those of flexion; whence there results an antagonism between these two parts of the spinal cord. The posterior strands produce a relaxation of the sphincter of the bladder, and the contraction of that of the rectum; the anterior, on the contrary, preside over the contraction of the sphincter of the bladder, and the relaxation of that of the rectum. The anterior and posterior strands exert no influence upon sensibility, but only on motion. The white matter of the spinal cord is the exclusive seat of motility; while the influence of the gray matter, is confined to the sense of touch.

Experiments also seem to have ascertained, not only that the spinal cord is the source of sensation and motion of the trunk and limbs generally, but that the sensibility and powers of motion of any part of the trunk and limbs, depend on that portion of the spinal marrow from which it receives its nerves. If an animal is made to take strychnine, and the spinal marrow be laid bare, the convulsions in any part occasioned by the poison, are arrested by compressing that part of the spinal cord which corresponds with it; while compression of the brain, or of the medulla oblongata, neither suspends nor checks them in the slightest degree. This fact appears to prove, that the spinal marrow is not *merely* a channel of communication between the brain and the organs of motion, but that the principle of motion resides in this part itself.

Experiments also make it probable, that the different portions of the spinal cord are capable of acting independently of one another; a fact which confirms the opinion that the spinal marrow has a power of its own, independent of the brain. Mayo remarks, that the spinal cord consists of an assemblage of independent segments; that each segment, from which a pair of nerves arises, has in itself a mechanism of sensitive and instinctive action, similar to that of analogous parts in the invertebrated animals. In proof of this he adduces the following experiments. If the spinal cord be divided in the middle of the neck, and again in the middle of the back in a body, a few seconds after it has been deprived of life, upon irritating a sentient organ connected

with either isolated segment, muscular action is produced. If, e. g. the sole of the foot is pricked, the foot is suddenly retracted in the same manner as it would have been during life. In this experiment a sentient organ is irritated, and the irritation is propagated through the sentient nerve to the isolated segment of the spinal cord, and gives rise to some change, followed by a motific impulse along the voluntary nerves to the muscles of the part.

Still, the peculiar energy of the spinal marrow, is subordinate to the influence of the brain, which perceives and appreciates the impressions conveyed to it from the sense of touch through the spinal cord, and which reacts in such a manner, that its influence is transmitted through the same channel to the locomotive organs. Without the action of the cerebral lobes, no *voluntary* motion could be originated, and probably no sensation be distinctly and consciously felt.

Influence of the Spinal Marrow over the Organic Functions.

The spinal cord also exercises an important influence upon some of the organic functions most necessary to life. The superior part of the spinal cord, or the medulla oblongata, may be regarded as a kind of focus of vitality in the superior classes of animals. In this limited portion of the cerebro-spinal system are concentrated all the nervous forces immediately necessary to life; particularly the nerves which give energy to the lungs, the larynx, the heart, and the stomach, and those which supply the external muscles of respiration; and any cause which should at the same time suspend the action of all these nerves, would immediately annihilate life.* Hence, the instant death occasioned by an injury of this part of the spinal cord. According to Bellingeri, the lateral strands of the medulla, which are continuous with the *corpora restiformia*, preside over the organic and instinctive functions.

Respiration, especially, is under the influence of the superior part of the medulla spinalis; and lesions of this part of the cord are always accompanied by symptoms which point out the dependence of respiration upon it. Lesions of the medulla oblongata instantly annihilate respiration. Injuries of the spinal cord opposite to the second vertebra, also, occasion instantaneous death; because all the respiratory nerves are then injured simultaneously, so that respiration is instantly destroyed by a paralysis of the external and internal muscles of the chest, and those of the neck and nostrils, and by the inaction of the aerial passages and lungs. If the spinal marrow be wounded opposite to the

* Ollivier.

fifth cervical vertebra, or a little higher, respiration becomes laborious, and the motions of respiration are executed only by the muscles of the neck and shoulders, the diaphragm becoming nearly motionless, and the intercostal muscles paralysed; and death soon follows from asphyxia. If a lesion be inflicted upon the dorsal portion of the spinal cord, it is followed by immobility of the ribs, because the intercostal muscles derive their nervous influence from this part of the cord. Respiration, however, is still carried on imperfectly by the action of the diaphragm, and the respiratory muscles, accompanied by the elevation of the shoulders, expanding of the nostrils, opening of the mouth, &c.

It may be asked why a simple section of the spinal marrow at the occiput produces death, when no other injury is inflicted upon the medulla spinalis, than the mere separation of its vertebral from its cerebral portion. Brachet answers this question by observing that the pneumogastric nerves, which originate in the medulla oblongata, receive in the lungs the impression of the want of respiration, and transmit it to the medulla oblongata. In the normal state, the medulla oblongata reacts upon those parts of the spinal cord which give rise to the respiratory nerves of the chest. But if the communication between the medulla oblongata and the vertebral parts of the cord be intercepted, the former can no longer transmit its influence to the latter, which, consequently, do not excite the respiratory muscles to action.

The effect upon respiration of dividing the pneumogastric nerves, is another illustration of the influence of the medulla oblongata on this function. The division of these nerves in the neck, produces a paralysis of the lungs, which soon terminates in asphyxia and death. It also occasions a paralysis of the muscles which dilate the larynx, in consequence of which the aperture of the larynx becomes closed, and opposes an insurmountable obstacle to the introduction of air in the lungs. It is supposed, also, to prevent the transmission of the sentiment of the want of respiration to the medulla oblongata, and consequently the reaction of this upon that part of the spinal cord which furnishes the respiratory muscles of the chest with nerves.

The influence of the spinal marrow upon the *circulation* of the blood, is by no means so great as upon respiration. Even the total destruction of the cord does not occasion an immediate suspension of this function. Experiments, however, have ascertained that the circulation of the blood is considerably influenced by the spinal column. The destruction of the spinal marrow, or of any considerable portion of it, has been found to enfeeble the action of the heart. If the lumbar part of it be destroyed, the circulation is enfeebled in the posterior extremities, but is not affected in other parts of the body, which derive their nervous influence from that part of the cord which is situated above the

injury. And, in general, when any portion of the spinal cord is destroyed, the circulation becomes more feeble in the parts situated below the injured portion of the spine, than in those above. On the whole, it is ascertained that the action of the heart is independent of spinal innervation, but is much *influenced* by it. The heart may act without the spinal cord, but yet is subjected in some degree to this nervous centre. If the heart be deprived at once of the influence *both* of brain and spinal cord, the action of the organ, according to Hall, is enfeebled from that moment. The heart, like the muscles of voluntary motion, possesses a degree of irritability independent of the great nervous centres; but if separated from them, it gradually loses this power. From the moment of the removal of the brain and spinal marrow, its irritability begins to fail. The circulation becomes weaker, and then ceases, first in the remoter parts of the system, then in those nearer the seat of the moving power.

Flourens was of opinion that the circulation depends upon the medulla oblongata, and that the power of the heart is impaired by the destruction of this portion of the nervous system, only because respiration is annihilated. But Hall found that the medulla oblongata in a frog might be destroyed so as to annihilate respiration, yet the circulation, though at first enfeebled by the shock, recover itself and continue perfectly vigorous for many hours.

But the *capillary circulation* appears to be immediately dependent upon the innervation of the spinal cord. The destruction of any part of this nervous centre, always produces a suspension of the circulation of the capillary vessels of the parts which receive their nerves from the destroyed portion. Hence in paraplegia from an injury of the spine, the capillary circulation is sometimes almost wholly suspended; the skin is purple or mottled, from a stasis of venous blood in the small vessels. The cutaneous veins are much enlarged and crowded with dark-coloured blood, from the loss of their contractile power; there is a total absence of cutaneous transpiration; the skin is dry, and there is a constant exfoliation of the cuticle. There is also a sensible diminution in the temperature of the paralysed parts. The developement of caloric in the system seems to take place in the two capillary systems, the pulmonary and the general; and both these systems derive their nervous influence in a great measure from the spinal cord. Hence, in chronic affections of this organ, attended with a loss of sensation and motion, there is a sensible diminution of temperature, of which the patient complains. Calorification, however, is not under the exclusive control of spinal innervation. The whole nervous system is probably concerned in it. It may perhaps be contended that the suspension of the capillary circulation in such cases, is owing to an

enfeebled action of the arteries of the part. This might be admitted, if we suppose, with Hall, that the arterial trunks possess muscular coats, or proper irritability. In fact, the explanation of the phenomenon, depends on the question whether the vascular irritability, the power which is destroyed, in the examples under consideration, appertains to the arterial canals, or the capillaries; for the action of the heart is obviously out of the question in the solution of the phenomenon. But the most important circumstance in these cases, in relation to the functions of the spinal cord is, that the part of the vascular system *below* the seat of the lesion of the spine, is paralysed and deprived of its power of moving the blood; a fact which demonstrates not only a certain general dependence of the *circulating vessels* upon the spinal cord, independently of the heart, but the influence of different portions of the cord upon the vessels of the parts which they respectively supply with nervous power.

That the spinal cord exerts an influence upon *digestion*, is ascertained by pathological facts, and by experiments on living animals. Thus, it has been observed, that the digestive functions are performed slowly and imperfectly in individuals affected with chronic diseases of the spine. According to Bourdon, lesions of the dorsal portion of the cord, are almost always accompanied or followed by colics, indigestion, obstinate affections of the kidneys, spleen, liver, ovaria, &c. Obstinate constipation, followed by involuntary evacuations, is a common symptom of affections of the spinal cord. The section of the cord between the fifth and sixth dorsal vertebræ in a dog, was found to destroy the power of evacuating the bowels, an effect which was undoubtedly owing, in part, to paralysis of the abdominal muscles, but which was partly to be ascribed to a loss of power in the muscular coat of the intestines, produced by the section of the cord.* From its power of stimulating the spinal cord, Serres recommends the tincture of *nux vomica* in injections and frictions on the abdomen and lumbar region, in lead colic, and in protracted parturition from torpor of the uterus.

The influence of the medulla oblongata upon digestion, is illustrated by the effect upon chymification, produced by the division of the pneumogastric nerves. This operation in living animals has been found to produce a paralysis of the stomach, by which the muscular contractions of the organ are annihilated, and chymification brought to a stand. It appears, therefore, that the contractions of the muscular coat of the stomach, as well as those of the fibrous tissue of the bronchial tubes, depend on the influence of the medulla oblongata, transmitted by the pneumogastric nerves.

* Ollivier.

The functions of *the kidneys*, also, are subject to the influence of the spinal marrow. In certain cases of injury or disease of the latter, the secretion of urine is totally suspended, and in others, it is more or less changed. The division of the spinal cord in the neighbourhood of the dorsal and lumbar vertebræ, or the total destruction of it below the last cervical vertebra, has been found entirely to change the qualities of the urine, which has become perfectly limpid, like water, containing little or no animal extractive matter, but much saline and acid principles. The destruction of the medulla oblongata, and of the cervical portion of the cord, has occasioned an immediate suspension of the urinary function, though respiration was maintained by artificial means. Chronic affections of the cord are sometimes accompanied by a morbid state of the bladder; as, chronic inflammation, or a copious secretion of vesical mucus. It has also been remarked, that paraplegia is a disease which, of all others, is most apt to occasion saline incrustations on sounds left in the bladder.

The inferior part of the spinal cord appears to be necessary to the contraction of the uterus in parturition. Females who had previously borne children, have subsequently lost the power of giving birth to children, by an attack of paraplegia. No dilatation of the neck of the uterus, no expulsive pains, nor contraction of the organ has occurred at the time of pregnancy, and instrumental aid has become necessary.

The division of the lumbar part of the cord in rabbits, bitches, and some other animals, some time before the period of parturition, has been found to prevent this process; and the animals die undelivered.

If the section of the cord be made after parturition has commenced, the uterine efforts suddenly cease, and delivery is prevented.

On the other hand, the irritation of the spinal marrow in this region, produces abortion. Even in pregnant animals, abortion has been produced after decapitation by passing a wire downwards into the spinal canal. As soon as the stylet has reached the lumbar region, uterine contractions, terminating in delivery, have taken place. In female rabbits and guinea pigs, the injection of the tincture of nux vomica into the crural veins, produces the same effect.

According to some physiologists, the spinal marrow presides over the functions of *nutrition*. Rachetti* remarks, that the energy of nutrition in animals, is in the inverse ratio to the mass of the brain, and in the direct proportion to the volume of the spinal marrow. It is to the predominance of this part of the nervous system, according to the same physiologist, that the crus-

* Ollivier.

tacea, insects, and worms, owe the remarkable property which they possess, of reproducing parts which have been removed, or accidentally destroyed.

The numerous connexions of the spinal marrow with the great sympathetic, which has been generally considered as the nervous system of organic or vegetative life, strengthen the opinion that the former exercises some influence upon the organic functions. The connexions of the great sympathetic and the spinal marrow are so intimate as to have led some physiologists to the opinion, that this nerve has its origin in the spinal marrow, or derives from the latter the greatest part of its nervous energy; and, in confirmation of this opinion, it has been observed, that the developement of the great sympathetic, in different classes of animals, is always in the direct ratio to that of the spinal marrow. On the whole, it may be observed, that of all parts of the nervous system, the spinal marrow is most indispensable to life.

Of the Nerves.

It has already been observed that there are forty-three pairs of nerves which originate from the cerebro-spinal system, viz. two from the cerebrum, five from the pons Varolii, five from the medulla oblongata, and the remaining thirty-one from the vertebral spinal column. The structure of these cords has already been described.

The cerebro-spinal nerves are subservient to sensation and motion; some of them to one of these functions only, the others to both. Thus the nerves of sight, hearing, and smell, are nerves of sensation only; the oculo-motory, the trochlearis, the abducens, and some branches of the fifth pair, and the facial, are nerves of motion. But, with these exceptions, the nerves are both sensitive and motive; or, as the German physiologists express it, *indifferent.*

In their peripheral extremities, the nerves either retain their distinct and independent character, as is the fact with the optic, acoustic, &c.; or they become amalgamated with the other tissues. The more highly a nerve is endowed with power, the more independent and isolated it is from the other soft parts. Thus, the nerves of specific sensation, as the olfactory, the acoustic, and the optic, preserve their individuality in their peripheral expansions. While the nerves of common sensation, as those of the skin, are confounded and melted, as it were, with the tissues of this membrane, so as not to be separable or distinguishable from it. The periphery of the nervous system, however, is not confined to the outer skin, or the external parts of the body, but exists every where, where nerves are expanded, as in the muscles, the parenchyma of most of the organs, and some of the membranes.

Cranial Nerves.

The nerves which originate from the base of the brain are twelve pairs, and are called cerebral or cranial nerves; the remaining thirty-one, which arise from the spinal marrow, are termed vertebral nerves. Of the cranial nerves, some are possessed of specific sensibility, as the *olfactory*, the *optic*, and the *auditory*. There are others subservient to voluntary motion, as the *third*, the *fourth*, the *sixth*, perhaps the *seventh*, and the *eleventh;* and a third class, whose functions are of a mixed character, as the *fifth*, the *tenth*, and perhaps the *ninth*, or the *glosso-pharyngeal.*

1. *Nerves of specific sensation.* These are the *first*, *second*, and the *eighth*, or *portio mollis* of the *seventh.*

The first, or the *olfactory* nerve, rises by three roots from the fore and under part of the corpus striatum, and, dividing into numerous fibrils, passes through the foramina of the ethmoid bone, and is distributed on the septum narium, and the adjacent surface of the upper turbinated bone. This is considered as the nerve of smell.

The second, or *optic*, is conducted to the optic thalami and the tubercula quadrigemina by two bands, which are extended from these eminences to the optic thalami. The two nerves unite in front of the pituitary fossa, and afterwards separate, and pass through the optic foramina, arrive at the posterior and inner part of the eyeball, and, piercing the sclerotica and choroides, terminate in the retina. This is the nerve of vision.

The *auditory*, or eighth nerve, frequently called the *portio mollis* of the seventh, rises by two roots from the medulla oblongata. It accompanies the facial or the seventh, as long as it is contained in the cranium, and the internal auditory canal. At the bottom of this canal, it divides into branches, which are distributed to the cochlea, vestibule, and semicircular canals.

These three nerves, together with the fourth pair, are isolated and have no anastomoses. They communicate only with the brain, and the organs to which they are respectively distributed; having no connexion with the spinal marrow, nor with the great sympathetic. All the other nerves are connected together by communications, more or less numerous.

2. *Nerves of voluntary motion.* The cranial nerves, subservient to voluntary motion, are the *third*, the *fourth*, the *sixth*, the *seventh*, and the *eleventh.*

The third pair, or the *motores oculorum*, arise by several filaments from the back part of the crura cerebri. This nerve is distributed to five muscles in the orbit of the eye, and sends a filament to the lenticular ganglion. By this ganglion it communicates with the fifth pair, and with the great sympathetic.

The fourth pair, or the *pathetic*, are the slenderest nerves in the body. Each of these is attached by three or four filaments, beneath the tubercula quadrigemina and the lateral part of the valve of Vieussens. They supply the superior oblique muscle of the eye.

The sixth nerve takes its apparent origin from the outside of the anterior pyramid at the edge of the pons Varolii, and supplies the abductor muscle of the eye. It communicates with the third and the fifth pairs, and by means of these, with all the other nerves, except the four which have been mentioned as isolated from the rest.

The eleventh, or *hypoglossal* nerve, arises from the fore part of the olivary tubercle by several filaments. These are collected together in two fasciculi, which unite to form one nerve. This nerve supplies the flesh of the tongue and several muscles of the throat, on which it bestows the power of motion.

The seventh pair, or *facial* nerve, frequently termed the *portio dura* of the seventh, rises apparently between the corpora olivaria and restiformia. It enters the internal auditory foramen with the acoustic nerve, then leaves the latter, and passes out of the cranium by the stylo-mastoid foramen. It receives a filament of the *Vidian nerve*, which enters the cavity of the tympanum, under the name of the *corda tympani.* The facial nerve furnishes filaments to the muscles of the tympanum, and the teguments of the ear. Upon emerging from the cranium, it enters the parotid gland, and is distributed to the muscles and teguments of the face. The seventh, according to Bell, is a nerve of *instinctive*, but according to Mayo, of *voluntary* motion.

3. *Nerves of a mixed function.* These are the *fifth*, the *tenth*, and perhaps the *ninth*, and the *twelfth*. The *fifth*, or *trifacial*, are the largest of the cranial nerves. They emerge from the sides of the pons Varolii in two fasciculi or roots, upon the larger of which, or the posterior, is formed a ganglion termed the *Gasserian.* Each nerve afterwards separates into three divisions, viz. the *ophthalmic*, the *superior maxillary*, and the *inferior maxillary.*

The first branch is distributed to the eyeball, the iris, the lachrymal gland, the schneiderian membrane, and the muscles and integuments of the forehead.

The second division, or the superior maxillary, is distributed to the schneiderian membrane, to the cheek, the nostrils, the palate, and the alveoli of the upper jaw.

The third division, or the inferior maxillary, is distributed to the alveoli of the lower jaw, the submaxillary, and sublingual glands, the tongue, the masseter, the pterygoid, the temporal, and the buccinator muscles, and to the integuments of the temple and chin.

The fifth pair communicates with the third, the sixth, the

seventh, the eleventh, and with the great sympathetic; forming of itself a kind of sympathetic nerve, by which all parts of the head are connected with each other, and with all other parts of the body.

According to Sir C. Bell, the branches of the fifth pair, which emerge upon the face to supply the muscles and integuments, are, like the spinal nerves, subservient to sensation and voluntary motion, jointly; but Mayo contends, that the facial branches of the fifth are exclusively *sentient nerves;* while the twigs which supply the masseter, the temporal, the two pterygoids, and the circumflexus palati, derived from the smaller fasciculus of the fifth, which is destitute of a ganglion, are nerves of voluntary motion.

The sentient branches of the fifth, are nerves of *common* sensation, viz. to the face, and to the organs of *specific* sensation, the eyes, nostrils, mouth, &c.; but its third branch, the inferior maxillary, furnishes the tongue with a nerve, which is considered as the gustatory nerve, or the peculiar nerve of taste.

The *tenth pair,* or the *pneumogastric nerves,* commonly called the eighth pair, arise from the medulla oblongata, immediately beneath the glosso-pharyngeal. They emerge from the cranium through the foramina lacera posteriora, in company with the ninth, or glosso-pharyngeal nerves, and the twelfth, or accessory nerves; and descend on the lateral parts of the neck, with the great sympathetic on the outer side of the primitive carotid, and posterior to the jugular vein. They distribute branches to the larynx, trachea, lungs, pharynx, œsophagus, stomach, duodenum, liver, spleen, and kidneys.

This important nerve establishes the principal connexion between the two departments of the nervous system, and is the bond which unites together the vital, nutritive, and animal functions. It forms a communication between the organs contained in the three great cavities of the body, viz. the brain, heart, lungs, and stomach. With the fifth and the seventh, it constitutes the principal connexion between the organs subjected to the will, and those which are not under the control of this principle. In a word, it unites the two lines of Bichat, the animal and organic. In its whole course it gives twigs to the ganglions, and contributes to form, with their own proper filaments, the principal plexuses of this system.

The branches of the pneumogastric nerves, which are distributed to the larynx, lungs, œsophagus, and stomach, appear to be nerves both of sensation and of involuntary motion.

The ninth, or *glosso-pharyngeal nerve,* is attached by several filaments in the line which separates the corpora olivaria from the corpora restiformia. These filaments unite into a single cord, which, after its exit from the cranium, sends a filament to

the auditory canal, and receives one from the facial, and another from the pneumogastric nerve. It furnishes branches to the root of the tongue, and to the upper part of the pharynx, and bestows the power of motion on the muscles of these parts. According to Mayo, the branches sent to the root of the tongue are sentient only, but those distributed to the upper part of the pharynx, are subservient both to sensation and voluntary motion; an opinion founded on the fact, that, on irritating the glosso-pharyngeal nerve in an animal recently killed, the muscular fibres about the pharynx were found to act, but not those of the tongue.

The twelfth pair, or the *accessory nerve of Willis*, arises from the lateral part of the spinal cord in the upper part of the neck, by numerous filaments, then ascends and enters the foramen magnum of the occipital bone, and passes out by the foramen lacerum posterius, with the pneumogastric, to which it sends a filament. It furnishes fibrils to the pharynx, but the greater part of it assists the spinal nerves in supplying the sterno-cleido-mastoid, and the trapezius muscles, on which it bestows the power of motion. It appears also to be a nerve of sensation; for, irritating it excites pain, and consequently in its functions it resembles the spinal nerves.

The Vertebral Nerves.

The vertebral nerves are more uniform in the manner of their origin, and regular in their distribution, than those which originate at the base of the brain. Each vertebral nerve arises by two distinct roots, an anterior and a posterior, and each of these roots is composed of several filaments. The posterior filaments form a ganglion before they join the anterior to make up the entire spinal nerve. These nerves, thus springing from two roots, possess the double property of conveying, in opposite directions, sensific and motive impressions. If a vertebral nerve is divided in any part of its course, the parts to which it is distributed are deprived both of their sensibility and of their power of motion. But if the two roots are divided separately, different effects are produced. The division of the anterior roots destroys the power of motion of the parts supplied by the nerve, without impairing its sensibility; while the section of the posterior roots, without affecting the power of motion, abolishes the sensibility. Each of these nerves, therefore, consists of two orders of filaments, which perform different offices, one conveying sensific impressions from the parts to which they are distributed to the spinal marrow; the other, transmitting motive impressions from the cord to the muscles of voluntary motion.

The vertebral nerves, then, are distinguished by the regularity

of their origin and distribution, from those which originate at the base of the brain. They differ from the latter, also, in originating by double roots, and in the circumstance that one of their roots swells out into a ganglion. One of the cranial nerves, and one only, viz. the fifth, resembles the vertebral nerves in these respects. On this account, the fifth pair of cerebral nerves is classed by Sir C. Bell with the vertebral; and is supposed to resemble them in its functions, as it does in its structure.

Functions of the Sympathetic Nerve.

The functions of the great sympathetic are not known. In the neck, and the canalis caroticus, it furnishes branches to the great vessels, and to the heart; in the chest, branches which are distributed to the viscera of the abdomen, and in the abdomen, others to the pelvic viscera. The same organs, however, are supplied with nerves from the encephalic system. The common opinion seems to be, that the great sympathetic presides over the organic or involuntary functions, as secretion, nutrition, absorption, calorification, &c. It is also supposed to be, as its name imports, the source of the numerous sympathies which unite the viscera of organic life into one great connected system. By some physiologists, the ganglions of this nerve are supposed to render the organs which are supplied with nerves from them independent of the will.

In herbivorous animals, which employ most of their time in eating, the sympathetic nerve is very large, corresponding with the voluminous viscera of these animals.

The sympathetic is possessed of scarcely any sensibility. Whatever may be the functions of this nerve, every part of the body must be under the influence of its innervation by means of the branches with which the blood-vessels are supplied, and which penetrate with them into the interior of all the organs.

Bell's Classification of the Nerves.

From the regularity of their origin and distribution, the spinal nerves, including the fifth cerebral, are termed, by Sir C. Bell, the regular, or the symmetrical nerves. They are distributed laterally to the two halves of the body, including both limbs and trunk, are subservient to common sensation, and to voluntary motion, and, as we are instructed by comparative anatomy, are common to every class of animals.

Most of the other encephalic nerves constitute, according to Bell, another system, which he terms the *superadded* or *irregular*, which he considers as forming a complex associated system, subservient to respiration. Sir C. Bell remarks, that the motions

dependent on respiration, extend nearly over the whole body, while they more directly affect the trunk, neck, and face. This is particularly true of respiration when in a state of unusual activity, or while the individual is under the influence of strong passion or emotion. There is also, a great variety of actions which are connected with respiration, and which require the aid of the respiratory muscles, such as coughing, sneezing, laughing, swallowing, vomiting, and speaking. Now all these actions, though not subservient to respiration, are so connected with this function, that they necessarily require the aid of the muscles of respiration, as well as that of others peculiarly destined to them; and this connexion establishes associations of the respiratory muscles with many others, and extends the influence of respiration over many other functions of the system.

Respiration, also, exists in various degrees of activity. In its ordinary state, and in sleep, it is an involuntary action. But, in many cases, as, e. g. when any obstruction exists to the ordinary movements of inspiration, or when it is intended to perform some voluntary action, which requires the aid of respiration, as smelling, or speaking, it requires the aid of volition. In dyspnœa, violent efforts are made to expand the thorax, by elevating the shoulders; and in highly excited respiration, the movements are not confined to the chest, but affect simultaneously the abdomen, thorax, neck, throat, lips, and nostrils. It is evident, then, that whatever may be the design of this extensive connexion of respiration with other functions of the system, it must be effected by an association of a great variety of muscles, animated by some common influence; and the nerves concerned in establishing this connexion, are termed by Bell the respiratory nerves, and form a system distinguished from the spinal, by the irregularity of their distribution. They originate also from one root only, and are destitute of ganglions at their origin.

These nerves arise very nearly together in a series, from a tract of medullary matter on the side of the medulla oblongata, between the motor and sensitive columns. From this fasciculus, or column, arise in succession, from above downwards, the *portio dura* of the seventh, the *glosso-pharyngeal*, the *par vagum*, or tenth pair, the *spinal accessory*, and, as Bell thinks, the *phrenic*, and the *external respiratory*. Bell also supposes that the branches of the intercostal and lumbar nerves, which influence the intercostal muscles, and the muscles of the abdomen in the act of respiration, are derived from the continuation of the same cord or slip of medullary matter. The respiratory, or superadded system of nerves, therefore, consists of the portio dura of the seventh or the facial nerve; the tenth or pneumogastric; the phrenic, which is distributed to the diaphragm; the spinal acces-

sory, which supplies the muscles of the shoulder; and the external respiratory, which is spent on the outside of the chest.

Hall's Classification.

Hall has made a new classification of the nerves and nervous system, which appears to have a foundation in physiological truth. He divides the nervous system into, 1. The *cerebral,* or *sentient* and *voluntary.* 2. The *true spinal,* or *excito-motory.* 3. The *ganglionic,* or *nutrient, secretory,* &c. The second class, or the *excito-motory,* he claims the merit of having first pointed out himself.

The 1st class comprehends all parts of the nervous system which are concerned in *sensation* and *volition,* the nerves of specific *sensation* and of *touch;* and those of *voluntary motion.* The cerebrum and cerebellum are the centre; its sentient nerves proceed from the organs of sense and from the external surfaces, inwardly towards the centre; its voluntary nerves pursue a course the reverse of this, from this centre to the muscles of voluntary motion.

The *sentient* nerves belonging to this class are: the first; second; fifth; eighth, or auditory; the ninth, glosso-pharyngeal or gustatory; and the *posterior spinal.*

The *voluntary* are: the third, or *oculo-motory;* the minor portion of the fifth; the *myo-glossal,* or twelfth; and the *anterior spinal.*

The 2d class, the *excito-motory,* or *true spinal,* comprises the tubercula quadrigemina, the medulla oblongata, the medulla spinalis, and the true spinal nerves, embracing the *excitors* and the *motors.*

(*a*) The *excitors* belong chiefly to the *fifth,* the *pneumogastric,* and the posterior spinal nerves. The excitor branches of the fifth, going to the eyelid, nostril, fauces, and face; those of the pneumogastric, to the larynx, pharynx, lungs, and stomach; those of the posterior spinal nerves, to the *anus,* cervix vesicæ, cervix uteri, and general surface of the body.

(*b*) The motor or reflex branches are: the seventh, to the *orbicularis;* the fourth and sixth, to the eyeball; the tenth, or pneumogastric, to the larynx and pharynx; the *spinal accessory,* the *phrenic,* and the *inferior external respiratory,* to the muscles of respiration; the spinal nerves, to the sphincters, ejaculators, and uterus. Spinal nerves are also distributed to the general muscular system, as nerves of tone.

The 3d class is composed of two divisions, an internal and external. The *internal* includes the sympathetic, and probably filaments of the pneumogastric. The external ganglionic embraces the fifth and the posterior spinal nerves.

The existence of the 2d class, or division, which forms the chief peculiarity of Hall's classification, is founded upon various

facts and experiments. In an animal stunned by a blow with an axe on the head, and deprived of sensation and voluntary power, mechanical irritation by a sharp instrument, as pricking or lacerating the face or surface of the body with a nail or pin, excited no motion, nor any evidence of sensation; but when the *eyelash* was *touched* with a *straw*, the eyelid was forcibly closed by the action of the *orbicularis;* and when the cornea was touched, the eyeball rolled outwardly by the action of the *abducens.* When the margin of the *anus* was touched, the sphincter contracted forcibly, the tail was raised, and the vulva was drawn towards the anus; motions which were executed after the abolition of consciousness and volition; and which Hall terms *excito-motory.* Respiration also continued. The upper part of the medulla oblongata was then destroyed, when, after some convulsions, respiration ceased, and the eyelid and eyeball remained motionless on the application of stimuli. In like manner, the division of the spinal marrow below the occiput, in a frog, instantly abolishes all traces of sensation and of voluntary power. All is still. But on pinching a toe with the forceps, both posterior extremities are *excited* to motion. If the integuments be pinched, the excito-motory phenomena are immediately produced. But on destroying the spinal marrow with a probe, these results are no longer obtained; the limbs remain motionless notwithstanding the toes are pinched.

Cerebral diseases confirm these conclusions. In apoplexy there is complete insensibility, blindness, deafness, &c., yet respiration continues, and the sphincters do their office. In hydrocephalus there is perhaps total blindness, with dilatation of the pupil; and the eye does not wink on the near approach of a finger to the cornea; yet a slight touch of the tip of the eyelid produces an immediate closure of the eye.

Filaments of the fifth pair are the excitors of the edges of the eyelids and surface of the eyeball, of the nostrils, face, and perhaps the fauces; and are the agents *first* concerned in causing closure of the eyelids, in sneezing, vomiting, and sobbing, when the eyelash is touched, the nostrils irritated, the fauces stimulated, or cold water is dashed in the face. Other nerves convey the reflex influence from the *medulla oblongata* to the orbicularis, and the respiratory muscles in these cases.

Filaments of the pneumogastric are the excitors of the larynx and bronchia, the pharynx, and stomach, in the irritation produced by carbonic acid or a drop of water coming in contact with the larynx; in the dyspnœa caused by inhaling the dust of ipecac; in deglutition; in ordinary respiration; and in vomiting produced by antimony, or by calculi in the gall duct or ureter.

It is a curious fact, which serves to illustrate the functions of the excitory filaments of the fifth and the pneumogastric, that

irritating the former in the fauces induces vomiting, while exciting the latter in the pharynx occasions swallowing. Hence it has sometimes happened that a feather employed to excite vomiting by tickling the fauces, has, by being carried into the pharynx, excited an act of deglutition, and been drawn into the œsophagus. A similar result has sometimes occurred in the introduction of instruments or irritating substances into the urinary passages and into the rectum.

Respiration is regarded by Hall as belonging to the class of functions depending on the excito-motory system of nerves. He thinks it probable, from facts, that the acts of inspiration are *excited* by the contact of carbonic acid with the filaments of the pneumogastric in the lungs. It appears that after repeated deep inspirations, by which the air in the lungs, and of course the carbonic acid, is completely exhausted, respiration can be suspended longer than under ordinary circumstances. Hence the impossibility of suspending respiration beyond a certain time. Pinching the pneumogastric nerve in an experiment, produces an act of inspiration; but the fifth and the spinal nerves are also *excitor* nerves of this function. Hence dashing cold water in the face, and plunging into the sea or cold water, excites an act of inspiration. The medulla oblongata *combines* the action of the different muscles together in the acts of respiration.

Deglutition is also an excited act, requiring the presence of some stimulus or substance to be swallowed. Hence it is impossible to swallow several times in rapid succession, without taking something into the mouth. Yet the contact of the finger with the pharynx of a dog, by passing it through an incision into the throat, excited deglutition very evidently, in an experiment of Magendie.

Cold water dashed on the surface of the body excites other functions belonging to this class besides respiration. Applied in this manner to the feet and legs, it will sometimes cause a relaxation of the sphincters, and the expulsion of the urine and fæces. The first act of respiration after birth may be explained on the same principle.

The whole *tone* of the muscular system, Hall infers to be the result of an excito-motory function. He observes that the limbs of an animal, separated from their connexion with the cerebrum, become relaxed on destroying the spinal marrow. The limbs and tail of a turtle, whose head had been cut off, were irritated by a pointed instrument, or taper, and were instantly excited to rapid motion. The sphincter remained closed, and perfectly circular; and contracted still more forcibly on the application of a stimulus. On removing the spinal marrow from its canal, the limbs lost their firmness and tone, became perfectly flaccid, and no longer responded to stimuli applied to them; the sphincter

lost its circular form and its contracted state, and became flaccid and relaxed; the tail in like manner lost its tone, and was unaffected by stimuli. Similar effects are produced in separate portions of the animal, as the head, lower or upper extremities, and tail, when separated from the body.

The 3d division of the nervous system embraces the ganglionic nerves. Hall divides it into external and internal, the latter including the sympathetic, and perhaps a part of the pneumogastric; the former embracing *all* the other ganglionic nerves, especially the fifth and the posterior spinal. These last Hall supposes to be provided with ganglia like the sympathetic, because they are destined to a similar office; viz. nutrition. Hence he terms them external nutrient nerves, as the sympathetic constitutes the nutrient nerve for internal parts. In short, the fifth and posterior spinal nerves he regards as the external part of the ganglionic system. But these external ganglionic nerves involve sentient and excitory nerves with the nutrient; and hence their ganglia differ in appearance from the ganglia of the sympathetic, partaking in some degree of the character of plexuses. Hall adduces in proof of his views of the nutrient function of the fifth, the fact that if sensation in the face be abolished by disease or compression of the fifth within the cranium, the eye ceases to be nourished and is destroyed. If the loss of sensation be the effect of disease of the brain, the eye is not involved.

Psychological Functions of the Brain.

The psychological functions of the brain require a more extended notice in this place, although it is impossible even to touch upon them, without trespassing upon the domains of another science, Intellectual Philosophy. Some defect of method is unavoidable, and in itself of little consequence. In fact, in relation to the functions in question, Physiology and Intellectual Philosophy contemplate the same phenomena from different points of view; and in both cases it may assist us in obtaining clearer ideas of the objects we are contemplating, if we shift our position and view them under a different aspect.

The psychological functions of the brain may be divided into three classes, viz. the faculty of knowledge; the feelings or emotions; and the desires; or the cognitive, affective, and appetitive faculties.

I. *Faculty of Knowledge.*

This faculty, as may be inferred from its name, comprehends all those powers which are employed in acquiring knowledge. Knowledge, though referring to objects which exist out of

the mind, or to the mind itself, regarded as the object of its own powers, is itself purely a mental phenomenon; consisting in certain modes or affections of consciousness, which on an ultimate analysis, will be found to be composed of certain internal perceptions, which we term ideas, and of various connexions or relations existing between them. The acquisition of ideas then, and the discovery of the relations between them, and of the laws which regulate their succession, is the great office of the faculty of knowledge. The acquisition or formation of ideas may be called ideogenesis; the discovery of the relations or connexions between them is the office of judgment and reason. The order in which they succeed each other is determined by a law which has been called the association of ideas. Ideogenesis, judgment and reason, and association, therefore, are the three grand functions of the faculty of knowledge.

1. *Ideogeny.* The first of these powers, *ideogenesis*, is composed of several sub-faculties, all of which are called into exercise in the formation of ideas. But a faculty preliminary in its exercise to them all, and which, instead of belonging to their number, only furnishes materials or occasions for their exertion, requires first to be noticed. This is the power of sensation. Sensation is that affection of consciousness which is produced by the impressions made on the senses by external objects. Two things are to be carefully distinguished in sensation, viz. the physical and the psychological part of the process. External objects act upon or impress our organs of sense by their physical properties, and the impression itself is purely of a physical character. But a remarkable and inexplicable consequence of this impression is, that a certain feeling is excited in our minds, which has a strict correspondence with the nature of the impression, and of course, with the sensible qualities of the object which produces it, but which has not, and, from the nature of the case, cannot possibly have, any conceivable resemblance to the latter. This feeling is termed sensation.

The number of sensations which are excited in our minds by material objects are almost unlimited, and when illuminated by the powers of the understanding, furnish us with the most ample materials of knowledge, yet the whole world of sensation by itself, is incapable of imparting to us a single ray of knowledge. These varying states of consciousness must be brought under the cognizance of the intellectual faculty, to enable us to form from them a single idea, or to learn a single truth. In short, our sensations must be intellectualized before they can be converted into knowledge. As we are constituted, indeed, the senses are constantly exciting the faculty of judgment into action, so that sensation at a very early period of life becomes almost inseparably blended with perception. But the two powers are totally dis-

tinct in their origin, and may be clearly discriminated in their nature and results. A being endued with the mere powers of sensation, even in the highest possible degree, would be incapable of knowing or of learning any thing whatever. He would be simply conscious of certain sensations, or of various modifications of his own existence, and of nothing more. This consciousness would neither acquaint him with the existence of external objects, nor of himself; nor even with that of the sensations, of which he was conscious; for the knowledge of these facts necessarily involves ideas and perceptions, which sensation alone can never furnish. But if we now suppose him to be suddenly inspired with this subtle intellectual sense, and the phenomena of his consciousness to be brought under the eye of his own understanding, he would instantly *perceive* the objects which he only *felt* before; and not only these, but a multitude of others, which he had not before observed, because they are not visible to the eye of sense. New objects would be occasionally starting up from among those he had been contemplating, where they had been lurking, as it were, before, until the light of the understanding shone in upon them, and laid open their hiding-places to his view. Among the earliest truths he would thus acquire, would be the knowledge of his own existence, and that of the existence of external objects, as the cause of his sensations; besides numerous other ideas, which would immediately spring up in his mind, wholly unlike his sensations, and which by no power of analysis could be deduced from them.

It appears, therefore, that sensation is not one of the cognitive or intellectual faculties. Its proper office is to furnish materials or occasions for the exercise of these powers.

2. *Conception*. The actual formation of ideas may be said to commence with conception. By this is understood the faculty of reviving the states of mind, or of consciousness produced by sensible impressions, in the absence of the objects which occasioned them; or rather, it is the power of thinking of our sensations. This is the first and simplest exercise of the ideopoietic faculty. It furnishes us with all our sensible ideas, and in a certain sense, is the avenue by which all knowledge enters the mind. Our conceptions are faint images or copies of our sensations, and they form the first step in intellectualizing sensations, or in converting them into knowledge. Without this power, knowledge would be impossible. We should be merely subjects of various sensible impressions, which would be constantly giving place to others, and vanishing away without leaving a trace in the mind, by which they could be recalled. By means of this power, we are able to multiply copies of our sensations to any extent, to be employed afterwards as materials in various intellectual processes. Memory, imagination, and association, are modes of

this power. Of the physical part of this process we know nothing. But as in every case of sensation, there is a certain configuration of the organs of sense, produced by the impression of the external object, and a certain change also in the physical state of the brain, it seems probable, that in conception, a similar condition, both of the organ of sense and of the brain, exists, since the state of our consciousness in conception is a kind of shadow or faint image of that which exists in sensation. That such is the fact, seems to be proved by the phenomena of spectral illusions, which appear to originate not merely in the state of the mind, but also in the physical condition of the brain and nervous system, and sometimes in that of the organs of vision alone.

3. *Attention.* Another faculty, of essential importance in the production of ideas, is *attention*, or the power of directing the mind to a sensation or idea, or any of its elements; or of keeping the object we are viewing steadily before the mind, to the exclusion of all others. This faculty is one of the functions of the will. When an idea, or any of its elements, is made the object of attention, it starts out in strong relief from the cluster with which it was associated, and takes its place in the very focal point of the intellectual eye. It is to be remembered, that solitary impressions are never made upon us: we are constantly surrounded by multitudes of objects, all of which are appealing to our senses, and producing collectively very complex and mingled impressions, which without the power of attention could never be separated into their constituent parts, and converted into ideas. In this analysis, it is true, the power of attention is aided by the senses, as well as by certain powers of internal perception. Thus, a single object, as a peach, e. g., may address itself to several of the senses, as the sight, touch, smell, and taste, at the same time. The object is one, and is recognised to be such, yet the senses unconsciously analyze the collective impression produced by it into four distinct elements, which, diverging, as it were, from the object, and exciting their appropriate sensations in the different organs of sense, afterwards converge from these towards the centre of perception, where they reunite, and receiving certain intellectual elements from the mind, are organized into an idea of the object. These intellectual elements are necessary to complete the idea of the object, and they constitute the basis of many judgments which we form respecting it. Without them we could never know that the peach was any thing more than a collection of certain properties, without any basis or bond of union; or rather, we could know nothing whatever about it.

By this power, directed towards the phenomena of our own consciousness, we obtain the knowledge of our mental operations, states of feeling, and intellectual faculties. But in every case of this kind, to the results of the analysis of the phenomena of con-

sciousness, affected by attention, there is always superadded an element furnished by the mind itself, which is necessary to convert the *sentiment* into an *idea;* and until this is accomplished, nothing can be predicated of them by the mind, and no judgment whatever formed of them. We are necessarily conscious of all our mental acts and feelings. We are conscious of seeing, hearing, willing, thinking; of pain, pleasure, hope, joy, &c. By the exercise of attention, we are able to detach the idea of the mental act or feeling, from the confused and mingled field of consciousness, and by a certain mental abstraction, to bestow individuality and a kind of personal existence upon it, under the shape of a distinct idea. In this manner, we acquire ideas of our mental operations and affections, and by a further process, in which another faculty, judgment, is concerned, we obtain a knowledge of our mental faculties; ideas which consciousness alone could never furnish. It is probable that all the varying states of consciousness, sensation, volition, perception, &c., are accompanied each with a corresponding physical change in the state of the brain. And if this be admitted, it will not be difficult to conceive that the reflex, or intellectual act of the mind, may be exerted on any portion of this physical process, which will then become a special object of attention; and perhaps be performed with greater energy, or reiterated, so as to produce a stronger consciousness of itself; two circumstances in which perhaps the essence of attention as to its physiological and intellectual condition consists. In this manner the intellectual elements of an idea, as well as the sensible, may become objects of attention, and be isolated from their associates.

4. *Judgment.* Another important faculty employed in forming ideas is *judgment,* which is defined to be the power of perceiving the relations between objects or phenomena, or rather between the ideas we form of them. Now these relations constitute a distinct class of ideas, wholly different from those, between which they are perceived to exist. They are not derived from sensation, nor are they copies of any thing. They are the offspring of the mind itself, springing from a peculiar internal power of perception, which is termed judgment.

An immense number of ideas is derived from this source, for scarcely any two objects can be mentioned, between which some kind of relation will not be perceived to exist. The number of these relations, and of the ideas derived from them, is absolutely unlimited, and they constitute an inexhaustible source of knowledge. Let us take a single relation, e. g., that of *resemblance,* and contemplate for a moment its prodigious fecundity in ideas and materials of knowledge. Take any number of objects, the most dissimilar that can be conceived of, as, e. g., *a steam engine,* the moral essence, justice, a fit of the gout, and the idea of nothing,

and though at first we might be puzzled to conjecture any shadow of resemblance or analogy between them, yet a moment's reflection will teach us that they all agree, at least in one respect, viz. in being objects of thought to the same thinking mind; an agreement, or resemblance, which enables us to apply the same denomination (things *quasi* thinked of) to all of them, however dissimilar they may be to the same mind under every other point of view. And this agreement or resemblance is precisely as real, as far as it goes, as that between sensible objects which make similar impressions on the senses, as trees, flowers, quadrupeds, &c. In the above mentioned example, the resemblance consists in the sameness of relation of these objects to the human understanding. In descending from the most general relation of objects to the mind, we shall find that they assume other relations to the understanding, superadded to the universal one of being objects of thought; relations which are sources of other resemblances between them. Some have objective, others only subjective existence; i. e. some exist out of the mind; others exist only in it. The former include matter and spirit; the latter, mathematical and other kinds of intellectual truth. To pursue the descending series still lower, things which have a real or objective existence, may be divided into corporeal and incorporeal. The former, in addition to the two more general resemblances mentioned above, have another superadded to them, viz. *they all possess body;* the latter have the common resemblance of being all destitute of it.

In descending a step lower in the scale of this relation, we shall discover, that as hitherto resemblance appeared to consist in the sameness of relation to the human intellect, when we arrive at the class of corporeal substances, a new resemblance is superadded, which consists in the sameness of relation *to the senses.* For all corporeal substances possess certain relations to the senses, by means of which they produce certain impressions upon them, between which the judgment recognises the relation of resemblance.

In relation to the sense of vision, corporeal substances may be classed into visible and invisible; in relation to touch, into palpable and impalpable, and so on. These resemblances, consisting in similarity of relation to the senses, will be constantly accumulating as we pursue the division of the objects of thought in the descending scale. Thus, visible objects may be divided into coloured or colourless; coloured, into red, blue, green, &c.; palpable, into hard, soft, solid, liquid, &c. By a similar process, we discover resemblances between certain powers or properties of mind which enable us to class them together, and to bestow upon them certain common appellations. In the exercise of the senses, the judgment recognises the similarity of the pro-

cesses and all the acts of the senses are thus connected together by the relations of resemblance. So in perception, in willing, and in the acts of judgment itself. It is apparent then that this single relation of resemblance is pregnant with the most important results in the acquisition of human knowledge. It is the basis of all classification and all general knowledge; it is indispensable to the formation of language; and it is the germ of the vast science of mathematics.

All general knowledge is founded upon it; for it is only so far as objects resemble one another that the same things can be predicated of them. Objects are arranged in classes only in consequence of certain resemblances perceived to exist between them. Hence without this relation no classification would be possible; and all knowledge would be limited to particular truths.

Language is also founded upon this relation. All words in any language, except proper names, express general ideas; that is, ideas of objects, or their qualities and relations, which so far resemble each other as to receive the same common appellation. All names of objects, their qualities, actions, and relations, are general terms, and without the power of perceiving the relations of resemblance between the objects of thought, so as to lay a foundation for classification, language could never have been invented, for no intelligible language would have been possible. No word would admit of more than a single application, and hence it would be manifestly impossible to learn the signification of any word until it had become worthless and incapable of further application.

The idea of number, also, is derived from this perception of resemblance. The basis of number is unity. But the idea of *one* could never be detached from the idea of a single object, but by comparing it with one more object at least. The idea of unity is an intellectual element added to our idea of an object; but it cannot be disengaged from it but by repetition of the idea. The very essence of unity consists in its involving the idea of plurality, i. e., in its being convertible into plurality merely by repetition. The repetition of an impression or idea, therefore, is absolutely necessary to enable us to perceive the *oneness* of a single impression or idea, or to detach from it the intellectual element, *unity*, superadded by the mind. It is impossible for us to apply the term *one* to any words but such as are expressive of general ideas. Objects must be generalized by the relation of resemblance, before they can be individualized by annexing to them the conception of unity. Now number is the basis of the science of mathematics, which may therefore be traced to a single relation, that of resemblance between the objects of thought—as the power of abstraction is derived from the faculty of attention,

so generalization is the result of the same faculty, aided by the judgment in the perception of resemblance.

There is one important class of conceptions or ideas of a very peculiar kind, which are formed by certain primitive and intuitive judgments. In the ordinary exercise of judgment, the comparison of two ideas is necessary to enable the mind to perceive the relation between them. But in the case in question, a single idea only is presented to the mind, and it immediately excites another totally different from the first, but connected with it by an indissoluble relation. The idea itself instantly suggests or rather involves the relation, which leads by a fine film of thought, forming a kind of intellectual bridge, to a second idea or conception, wholly unlike the first, and especially distinguished by its irresistible necessity. Thus a single sensation or act of consciousness instantly suggests the idea and belief of our own existence, with a force of conviction which no power of reasoning can either increase or diminish. The idea of body, however formed, leads to the conception of space in which it exists; for space is the logical condition of the existence of body. It is impossible to conceive of body but as existing somewhere, that is, in space; and the moment this idea is formed, we feel an irresistible conviction of its absolute necessity, that is, we feel the impossibility of conceiving of the non-existence of space. The idea once formed, becomes wholly independent of that which suggested it, and from the narrow dimensions of the particular substance which first awakened it in our minds, it instantly swells to an illimitable and inconceivable extent, and becomes one of the most immovable convictions of the human mind. The idea of body, then, which is that of something both contingent and limited, leads to the conception of space, or of something which is of unlimited extent and of absolute necessity. In a similar manner are formed the idea of time, of infinity, of cause and effect, of substance, personal identity, and some others.

One most important idea, viz. that of right and wrong, and of merit and demerit, the former referring to certains actions, the latter to the agents who respectively performed them, may be traced to a similar origin. In performing certain actions we feel a certain sentiment, viz. that we have done right; in performing certain others, we are conscious that we have done wrong.

In attending to this consciousness, we separate the sentiment of right involved in it from the action which produced it, and this sentiment is then converted into the idea of right; we become sensible of the distinction of right and wrong, and we feel that it is engraved in indelible characters on the human mind. It immediately becomes a universal and necessary idea, and constitutes the basis of the science of morals.

As this class of ideas is distinguished by peculiar characters,

and as it is the result of a special function of judgment, the faculty by which they are produced is referred by some metaphysicians to a separate and higher power of the mind, viz. reason.

Reason has been defined by one of its most zealous advocates, as a distinct faculty, "the power of universal and necessary convictions, the source and substance of truths above sense, and having their evidence in themselves." It transcends experience, and, as Coleridge remarks, "it avails itself of a past experience, to supersede its necessity in all future time; and affirms truths which no sense could perceive, nor experiment verify, nor experience confirm." Stewart also suggests the appropriation of the term *reason* to the faculty by which these truths are learned.

From this brief analysis of the sources of our ideas, it will appear, that in relation to their origin, they may be divided into three classes, viz. 1. Ideas of sensation, or sensible ideas. 2. Ideas of judgment, or of relation. 3. Ideas of reason, or transcendental ideas.

A single impression made upon the senses by an external object, is sufficient to excite ideas of all the three classes. Thus, for example, let a person receive a blow upon the head from a hard substance, as a stone, and let us consider what ideas might be excited in his mind by this impression. 1. The idea of the impression. 2. The idea of himself as the subject of it. 3. That of the external substance which produced it. 4. The idea of causation, from considering the external body as the cause of the sensation. 5. The idea of space, as necessarily involved in that of the body. 6. That of time, derived from the idea of the duration of the impression; and several others.

Now none of these but the first are derived from sensation except chronologically. But by the constitution of the mind, the first suggests the others by a kind of primitive judgment; and thus an idea of sensation begets a numerous progeny of others, which bear no resemblance whatever to the parent idea. This serves merely to fecundate the mind, which contains innumerable germs of thought, which otherwise would never be developed.

II. *Judgment and Reason.*

From what has been said, it appears that judgment and reason are sources of ideas only indirectly; their true functions are to discover the connexions and affinities of thought; to perceive but not to individualize the relations between ideas. They connect ideas by a fine film of thought, a sort of intellectual bridge, which is termed a relation. By an act of attention, this is detached from the two ideas which it serves to connect, contemplated by itself, and converted into an idea. The process of the judgment then is synthetic. Ideas are placed in a mental juxtaposition by this

faculty, but they are afterwards separated by an act of attention, which seizes upon the intermediate or connecting idea, and bestows upon it a separate existence. Before this analysis has individualized the connecting idea, the relation is felt, but not, strictly speaking, perceived. But after the *sentiment* of relation has been converted into an idea by the attention, then, in a subsequent exercise of the judgment, the relation is not only felt, but *perceived;* and if expressed in language, it is then *affirmed.*

The office of judgment and reason then, is not the discovery of ideas, but of truths; they present us new ideas, not in a separate state, but folded up as it were with other ideas, in the form of mental propositions. From these the ideas of relation are disentangled by the faculty of attention, and then first assume the character of independent ideas.

A connected series or chain of judgments is termed reasoning, which is a progressive evolution of truth from certain premises or propositions. In all sound reasoning, the last proposition or conclusion is contained in the first. For example: 1. Man is a rational but selfish being. 2. A selfish being will seek his own interest, even at the expense of others. 3. A being who will seek his own interest even at the expense of others, needs some restraint for the security of others. 4. A rational being who needs to be restrained for the security of others, must live under laws. 5. Man must live under laws.

This last proposition, it will be perceived, is involved in the first, from which it is unfolded by a progressive analysis or series of judgments. This property of eliciting truth by linking a series of judgments together, is considered as one of the functions of reason, and is termed reasoning or demonstration. A third process employed by reason in the acquisition of truth, is induction. Intuition, demonstration, and induction, then, are the three means of which reason avails herself in the discovery of truth.

By *intuition* we have an immediate perception of truth, an irresistible conviction, neither requiring nor admitting the intervention of any *media* of proof. For example, we intuitively perceive our own existence, and our personal identity; we believe that every event must have a cause; that the testimony of our senses does not deceive us, &c.

Demonstration is the developement of an idea from one which is more general, and which contains it. It is the discovery of a connexion between two ideas, by means of a third which is more general than the two others, so as to comprehend them both, and connect them together. To demonstrate is to deduce the particular from the general, as in the example of reasoning adduced above. The scholastic form of demonstrative reasoning, is the syllogism.

Induction is a process which is the reverse of demonstration,

i. e., it proceeds from the particular to the general. The field of inductive reasoning is physical inquiry, in which we aim to establish general laws from particular facts. We resolve particular facts into others more general and comprehensive. "When, by comparing a number of cases, agreeing in some circumstances, but differing in others, and all attended with the same result, a philosopher connects, as a general law of nature, the event with its *physical cause*, he is said to proceed according to the method of induction." In this process we generalize the particular character of the phenomena, and this general character we call a law. We evidently proceed from the particular to the general, and not as in demonstrative reasoning, from the general to the particular. The immense acquisitions of modern physical science are trophies of the inductive reasoning.

Belief is but another name for judgment. We may indeed feel it to be the conviction of the mind, that what the judgment perceives it perceives truly, that is, that the judgment is not mistaken or in an error. But it is difficult to discriminate between the significations of the two terms. We judge or perceive that one man is taller or stouter than another, and we believe him to be so. The belief is always precisely as strong as the judgment.

Every judgment is an element of knowledge. The collective judgments which we form on any subject, constitute our knowledge of it, which will be more or less complete in proportion as our judgments are more extensive and numerous.

A complete system of judgments on any subject of knowledge, constitutes a *science*.

The Order or Succession of Ideas.

The order or succession of ideas, so far as it is spontaneous, is regulated by a law which has been erroneously termed the association of ideas. There is an uninterrupted current of thoughts, feelings, desires, sensations, and acts of the will, sweeping through the mind during our waking hours. It is absolutely impossible to stop it, though we have a certain control over the direction in which it moves. The very effort is only a new state of mind, which immediately mixes with the others, and is irresistibly hurried along with the stream. If we separate from this mingled and moving stream of consciousness, our sensations and volitions, which are constantly giving it a new direction, and suffer it to pursue its own spontaneous course, it will appear, upon examination, that this, instead of being wholly fortuitous and uncertain, is determined by certain fixed laws of thought, which are collectively termed the *association of ideas.* These laws will be briefly enumerated.

1st. *The law of coexistence.* When several ideas or feelings have been excited in the mind at the same time, if any one of them afterwards return, it is almost always in company with some of its former associates. This law seems to be founded in the unity of the mind, by virtue of which, states of mind which have formerly coexisted, whether consisting of ideas, emotions, judgments, &c. have a tendency to recur together.

2d. *The law of succession.* Ideas or states of mind which have once or repeatedly occurred in a certain order of succession, have a tendency to recur in the same, and never in the contrary order. Any one of the series may bring along with it the neighbour which immediately followed, but scarcely ever the one which went before in the original order. The difficulty of repeating the Lord's Prayer, of singing some familiar air, or of boxing the compass, backwards, is a familiar illustration of this law. Upon a moment's reflection it will appear that the first law may be included under this.

3d. *The law of resemblance.* Every one is acquainted with the fact, that when an object is presented to the mind, it frequently recalls the idea of some other entirely different, to which, however, it bears some resemblance, as when a portrait recalls the idea of the original, or a child which we see for the first time, brings to mind the image of his father. On the same principle, physical objects sometimes excite moral ideas, and *vice versâ;* thus, the white and stainless snow, may suggest the idea of spotless purity and innocence; affliction and distress, that of gloomy and overspreading clouds; while the curling waves and ripples of the ocean, sparkling and glancing in the sunlight, may picture themselves, on a poetical mind, as smiles and dimples on the visage of the ocean-god, as in the exquisite image of the Greek poet, ποντίων τε κυμάτων 'ανήριθμον γέλασμα. Illustrations may be multiplied to any extent. It is evident that this law will be more or less extensive in its operation, according to the greater or less aptitude in the mind to discover among different objects the relations of resemblance or analogy. The ground of the law lies in the fact, that objects that are recognised as similar, affect the mind in a similar manner; and that similar states of mind possess certain common elements, which form an easy medium of transition from one to the other.

4th. *The law of contrast.* Contrast, or opposition of qualities, is another principle of suggestion; that is, there is a tendency in the mind to pass from objects to their opposites. Thus a dwarf may suggest the idea of a giant, a fact of such common occurrence, that a very diminutive person is sometimes jocularly or in derision called a giant. On the same principle, a very ugly or deformed person may be called an Apollo; a blockhead, a Newton; &c. A palace may excite the idea of a hovel; wealth, that of

poverty; light, of darkness, &c. The source of this tendency of the mind lies in this, that opposites are contrary extremes; and that an object or quality is extreme only in comparison with its opposite, which of course it naturally suggests, or rather, implies. The very idea of degree, involves the coexistence in the mind of the ideas between which it exists. One extreme, therefore, naturally suggests the opposite, for in fact it virtually involves the idea of it. The very idea of extreme, implies the greatest possible distance which separates an object or idea from another of the same kind, with which it is therefore necessarily brought into comparison. In fact, this law may be resolved into the preceding, or that of resemblance; one extreme naturally suggests another. In relation to the mind, the law seems to be founded in its tendency to oscillate from one point to the opposite one, before it regains its natural state of indifference.

5th. *The law of causality.* Any phenomenon, regarded as an effect, suggests to the mind the idea of its cause, and *vice versâ.*

6th. *The general law of relation.* This comprehends all the preceding, and embraces some others. It is apparent that any object whatever may suggest the idea of any other with which it is connected, by any relation perceived by the mind. The relation will form a bridge, which will easily conduct the mind from one idea to another, whether the relation be that of resemblance, contrast, coexistence, succession, or any other. All primitive or intuitive judgments furnish examples which fall under this general law. In fact, all the particular laws above alluded to, may be united under one general law, that of relation; and, consequently, association may be ultimately resolved into *judgment.*

The current of association is turned out of its natural channel by the occasional intrusion of sensation, and sometimes by acts of the will.

The occurrence of certain ideas which we have previously experienced, accompanied with the additional idea of their former existence, is ascribed to *memory.* It is, in fact, an example of association or suggestion, either spontaneous, or influenced by volition, but connected with the idea of past existence.

III. *Faculty of Feeling or Emotion.*

Sensations and ideas frequently excite certain vivid feelings entirely unlike themselves, and dissimilar to our intellectual states, which are termed emotions or affections; as, anger, joy, love, wonder, fear, &c. These feelings result from a perception or sentiment of certain qualities in the objects which excite our sensations, or which are represented by certain ideas excited in the mind. If a person receives a bodily injury from another, he

feels perhaps physical pain, and nothing more. But if he supposes the injury intentional, he experiences, besides bodily pain, a vivid emotion of the mind, impelling him to retort the injury upon the offender, a feeling which, if not gratified at the time, sometimes settles down into a cooler but deeper sentiment, which aims at the same result. Inanimate objects very often give rise to some of these feelings. Much of the scenery of nature, e. g., is calculated to excite in our minds the most diversified and powerful emotions; as, feelings of wonder, delight, of sublimity, beauty, cheerfulness, gloom, &c. Certain ideas of the imagination, also, as those which are suggested by reading an affecting narrative, may give rise to the most delightful or the most painful emotions, as joy, love, admiration, cheerfulness, &c., or, anger, contempt, disappointment, pity, &c. Certain states of the organization also are productive of these feelings.

These feelings are exceedingly numerous, and may be variously classed. There are some which do not relate to any particular object or time, such as cheerfulness and melancholy. There are others which relate to certain objects as existing at the present time, such as feelings of wonder, sublimity, and beauty. These Brown denominates *immediate* emotions. There are some which regard their objects as past, and necessarily involve this idea of the past; as remorse, revenge, gratitude, &c. These he terms *retrospective* emotions. There is a third class, which relate to future objects, or which look forward instead of backward. These are the *prospective* emotions. They comprehend the whole tribe of our desires and aversions, and of course belong to the third head.

In regard to the objects which excite them, the emotions may be divided into subjective and objective. The subjective relate to or centre in ourselves. The objective relate to other persons.

The subjective emotions are divisible into three classes. 1. Pride, love of power or wealth, vanity, shame, humility, cheerfulness, relate to the *present time*. 2. A good or evil conscience, repentance, remorse, relate to the *past*. 3. Hope, fear, courage, anxiety, suspense, despair, &c., refer to the *future*.

The objective emotions relate to other persons, and may be divided into two classes, of directly opposite characters, viz. love, friendship, approbation, gratitude, respect; and envy, jealousy, revenge, anger, contempt, hatred, cruelty, &c.

These feelings constitute the principal sources of the enjoyment as well as of the sufferings of man; and on their due regulation most of the happiness and true value of human life depends. When they acquire a certain degree of permanence and strength, so as to get the mastery of the reason and judgment, they are termed *passions*. Some of them, however, are of too mild and

placid a character ever to receive this name; as cheerfulness, contentment.

The passions have a very conspicuous influence upon many of the functions of life, and in reference to the opposite characters of this influence, have been divided into the two classes; viz. *exciting* and *depressing* passions.

The former, as hope, joy, love, anger, &c., in a moderate degree, increase the nervous and muscular energy, promote the circulation of the blood, augment animal heat and cutaneous exhalation, and in certain enfeebled states of the system, from sickness or other causes, may act as beneficial tonics. But when violent or excessive they are capable of producing very injurious and even fatal consequences. Sometimes they stimulate the system to such a degree as to excite fever; and some of them, as excessive joy or ungovernable rage, may prove suddenly fatal, by paralyzing the brain or the heart, or by causing a rupture of the latter or some large blood-vessel, especially in the brain, and thus causing or giving rise to apoplexy.

The depressing passions, as fear, sorrow, anxiety, home-sickness, shame, despair, always enfeeble the powers of the brain and heart, and, in an excessive degree, may produce paralysis of these organs, or of some part of the muscular system. Thus vertigo, swooning, and temporary paralysis of the organs of locomotion or speech, may be the effects of these passions. But it is a curious fact, that under certain circumstances, when suddenly excited, these passions have sometimes operated as powerful stimulants to the brain and muscular system. Thus a sudden fright has been known to restore to a person the use of his limbs or his speech; and feeble persons have been so much invigorated by fear, that they have acquired strength to move burdens which required the united strength of several men. But this temporary excitement of the nervous and muscular power has usually been succeeded by still deeper depression.

Faculty of Desire.

Objects, or their ideas, frequently excite a wish to possess or a desire to avoid them. If an object be agreeable to the senses or the imagination, the idea of it also is grateful, and its valuable qualities are often exaggerated by the faculty last mentioned, when reason is frequently called upon to make a sober estimate of its real value. If both agree in their report, a third faculty of the mind is called upon to enable us to obtain or avoid the object. This is the *will*. If the two other powers—reason, and imagination or inclination—disagree, the mind of the individual becomes the theatre of a conflict between them, the result of which

will determine, *quoad hoc*, whether the person is a rational being or not. The absolute authority of reason constitutes the highest freedom of the will. The greater the power and dominion of reason in our moral determinations, and the less the influence of our irrational inclinations, the freer is the will, or rather they who exercise it; and *vice versâ*. The will then is the term of our desires and inclinations as well as of reason.

Volition is a conscious attempt to do something which we feel or think we have power to do. The result of it is generally supposed to be limited to muscular action. The contraction of the muscles of voluntary motion in the natural or healthy state, takes place exclusively under the influence of this power. Locomotion, respiration, and speech, are examples of voluntary action. Respiration, however, is carried on without any conscious effort on our part; though we have the power of suspending it for a short time by a voluntary effort. It also continues without interruption during sleep, though consciousness and volition are then slumbering with the other animal functions. Respiration is therefore only in part a voluntary function; i. e. the influence of the will over it is very limited.

But there is another theatre besides muscular contraction for the display of this power; viz. the field of sensation and of internal consciousness. The will is exerted not only in exciting the action of the voluntary muscles, but in scrutinizing our sensations, and in fixing the mind on certain ideas or feelings, or in directing the current of our thoughts into new channels. When we listen attentively to certain sounds; e. g. fix the attention on a certain voice or instrument among the mingled sounds of a concert of music; when we examine the colours and shape of some beautiful visible object, &c.; when we analyze by the palate the scientific results of refined cookery; when we direct our attention to some idea as it is floating away on the current of consciousness, and seize upon and secure it before it disappears; when we purposely set about some intellectual investigation, or form some moral determination, &c.; in all these cases, our will is as much concerned as in lifting our legs in walking or dancing, exercising our jaws in eating, or even in exerting our muscular power in the most emphatic manner, as in raising a heavy burden. In fact, our voluntary muscular actions are frequently the result of two distinct volitions, which belong respectively to the two classes above mentioned. The mere muscular action which is accomplished by an act of the will, is only a consummation of a previous intellectual or moral act, which is no less the effect of the same power. A murderer first forms a deliberate determination, which is an act of the will, to perpetrate the deed; he then exerts another act of the same faculty to give effect to his design.

Instinct. There is another faculty, which remains to be noticed among the functions of the brain, which is instinct. Instinct is a blind impulse to certain actions necessary to the physical well-being of the individual, the continuance of the species, and the safety of the young. We know little about it except its results, many of which are very curious and admirable. It may be accounted for, however, by supposing that at particular times or periods, certain feelings or states of the nervous system are physiologically developed, which by the laws of the organization are communicated to the centre of the nervous system, and give rise automatically to certain acts, of the aim and nature of which the animal is unconscious, but which are necessary to the attainment of certain important objects. It is, in fact, an example of exquisite physiological mechanism.

In man, there intervenes between the feelings which prompt to actions analogous to the instinctive actions of brutes, and the actions themselves, the light of the understanding, imparting a knowledge of the aim or end of the action, and also suggesting means by which it may be accomplished. In proportion, therefore, to the developement of the understanding, instinct is superseded or confined within narrow limits. Yet there are instincts in man, and there is understanding in other animals. A faint light of the understanding sometimes glimmers between the instinctive feelings and actions of animals, apparently giving some knowledge of the aim or object of the actions, and suggesting means of bringing them to pass. And it is worthy of remark, that this resource in the understanding comes to their aid only when it is needed; i. e. only when the ordinary means of attaining the object fails and instinct is at fault.

In instinct, a physical impulse is the sole spring of the act, directly influencing the organization. In man, the physical impulse may exist, and may be irresistible by acting directly upon the organization; but there may also coincide an intellectual incentive or a rational motive acting upon the will, and impelling it to the same action, which will then cease to be purely an instinctive one, and become partly rational; or the rational or psychological impulse may wholly supersede the physical, and thus take the action entirely out of the domain of instinct. The organic and automatic nature of instinct is evident from the fact that instinct can never be improved; φυσεις ζωων ἀδιδακτοι.

CHAPTER XIV.

THE CIRCULATION.

The circulation of the blood is another of the *vital functions*, or one which is immediately necessary to life. The universal suspension of it throughout the body, is instantly fatal. Hence, diseases of the heart, and of the great vessels, are apt to terminate in sudden death, while morbid affections of the other vital organs, the brain and the lungs, however violent and acute, scarcely ever, if ever, occasion immediate death.

Life, or vital excitement, is maintained in all the organs by the presence of arterial blood. This fluid is the source of the nutrition of all the organs and tissues, and its presence is an indispensable condition to the performance of every function of the system. If an organ is deprived of arterial blood, from that moment its nutrition ceases, and it loses the power of executing its peculiar functions; and it is obvious that a universal suspension of the circulation, which distributes the blood to every part of the system, must instantly abolish every function of life.

The circulation does not exist in all animals, but only in those in which the alimentary matter is absorbed into the system instead of being *immediately* employed in nourishing it, and first converted into a distinct fluid, the blood, which furnishes the immediate elements of nutrition; and in which there also exists a *local* respiration; i. e. the absorption of air takes place separately from that of the other nutritive principles, and in a separate organ or apparatus. Two different kinds of matter are absolutely necessary to the nutrition of animals, viz, air, and certain solid and liquid substances, which are called food. The latter, or the food, is not capable of being converted into blood, before the former, i. e. the air, has acted upon it by one of its principles, oxygen. Now, if these two elements of the blood are not introduced into the system in the same place, but by separate organs, it is evidently impossible, that they can, immediately after their absorption, be employed in nutrition. It is necessary that one of them, after its absorption, be conveyed to the organ where the other is absorbed, and that the nutritive fluid, formed by their mutual action, be afterwards carried from this organ to all parts of the body, to furnish the materials for their nutrition, and vital excitation. Hence, a local respiration is always ac-

companied with a circulation; while in those animals in which respiration is disseminated, i. e. is not concentrated in a particular organ, as in insects, there is no circulation.*

The organs of the circulation are the *heart*, the *arteries*, the *veins*, and the *capillary vessels*. These organs collectively represent two trees of unequal size, whose trunks are united at the heart, and whose branches are infinitely ramified; those of the larger tree, throughout all parts of the system; and those of the smaller, throughout the lungs. At the union of the two trunks is found the central organ of the circulation, the heart.

The motion of the blood in this apparatus is a circulatory one. This fluid is forced out of the heart by the contraction of the organ, and propelled to every part of the body through elastic tubes, called arteries. From the extremities of these it passes into the minute organs of another set of tubes, termed veins, and by them is returned to the heart. According to some physiologists, there exists between the termination of the arteries and the commencement of the veins, an intermediate order of fine hair-like vessels, termed capillaries. The course of the blood, from and to the heart, is called the circulation.

The Heart. In the human species, in that class of the animal kingdom called the mammalia, and in birds, the heart is a double organ, consisting, in fact, of two single hearts, each of which gives motion to a distinct species of blood. One of them receives the dark venous blood which returns from all parts of the body, and transmits it to the lungs, where it is converted by respiration into scarlet-coloured arterial blood. This may be termed the *venous*, or the pulmonary heart. The other heart receives from the lungs the arterial blood, and conveys it to all parts of the system. This may be called the *arterial* or *aortic* heart. And these two hearts are united together into a single organ. Each of these two hearts contains two cavities, one designed to receive the returning blood from the veins; the other to propel it in the opposite direction into the arteries, and through them, to all parts of the body. The cavities, by which the heart receives the blood, are called *auricles;* and those which contract upon this fluid and force it out of the heart into the arteries, are termed the *ventricles*. The walls of the heart are composed of a muscular substance, the fibres of which run in various directions, interlacing one another, and forming an inextricable tissue. The parietes of the ventricles are much thicker than those of the auricles. The cavities are lined by a thin membrane, forming, by its folds, valves which sentinel the different apertures and outlets of the organ.

The heart is covered externally by a serous membrane, re-

* Adelon.

flected over it from the pericardium, a sac of a fibro-serous structure. This membrane secretes a fluid called the *liquor pericardii,* the use of which is to lubricate the organ.

The nerves of the heart are derived from a plexus formed by filaments of the pneumogastric and the great sympathetic nerves, and they follow the ramifications of the coronary arteries.

The heart is situated in the thorax, in the lower part of the anterior mediastinum. Its position is oblique, being inclined forwards, downwards, and outwards, and from right to left. Its posterior surface is nearly horizontal, and rests upon the aponeurotic centre of the diaphragm. Its anterior is turned a little upwards, and exhibits a groove passing from left to right obliquely downwards, in which is lodged the anterior coronary artery and veins. The base of the organ is directed backwards, and to the right towards the bodies of the dorsal vetebræ, from which it is separated by the aorta and the œsophagus. The apex is inclined forwards and to the left, and during life its pulsations are felt between the cartilages of the fifth and sixth ribs.

The figure of the heart is somewhat conical. The septum which separates its cavities, runs in the direction of its long axis, but in such a manner that the apex of the heart falls exclusively to the left ventricle. The chambers of the *pulmonary* or *venous* heart, more usually termed the *right* side of the heart, are triangular in their shape; while those of the *arterial,* which is also called the *left* side of the heart, are oval. Each of these cavities is capable of containing about two ounces of blood. The two auricles are so connected by their common septum, and by fibres passing from one to the other, that it is impossible for either to contract alone. The same is true of the two ventricles. They have a common septum, and there are whole layers of fibres common to both. On the contrary, the auricles and ventricles are connected with each other only by cellular tissue, vessels, and nerves. No muscular fibres pass from one to the other, and by maceration they may be easily separated from each other.

According to some physiologists, the right ventricle has a greater capacity than the left, because the venous system to which it belongs, is more capacious than the arterial. But others assert, that the superior capacity of the right side of the heart, is a cadaveric phenomenon, owing to the accumulation of blood in it, which occurs in the last moments of life; while the left side, in a state of vacuity, contracts to a smaller volume.

Each cavity of the heart is lined with a thin transparent membrane, which is continued from the ventricles into the corresponding arteries, and from the auricles into the veins which open into them. It is usually classed with the serous membranes.

Between each auricle and the corresponding ventricle is placed a valve, which is formed by a duplication of the inner membrane, strengthened by intervening fibrous substance. The free margin of these valves is irregular, and in the right side of the heart it presents three apices, but two only in the left. Whence the right auriculo-ventricular valve is termed the *tricuspid* valve, and the left, the *bicuspid* or *mitral.* The floating edge of the valves is attached to the fleshy columns of the ventricles by short tendinous threads, called *chordæ tendineæ.* The margin of the valves is strengthened by little granular bodies, termed *corpora sesamoidea.* These valves prevent the refluence of the blood from the ventricles into the auricles, during the contraction of the former.

Valves exist also at the origin of the two great arteries, the pulmonary artery, and the aorta, where these vessels communicate with the right and the left ventricles. These valves differ widely from the former. They are formed by folds of the inner membrane of the arteries, are of a semilunar shape, and are attached by their convex margin to the circumference of the artery, each occupying a third part of it. These are termed the semilunar, or sigmoid valves, and their office is to prevent a reflux of the blood from the aorta and pulmonary artery, into the corresponding ventricles.

The orifice of the inferior vena cava is also furnished with a duplication of its inner membrane, which projects into the cavity of the auricle, and is called the Eustachian valve. This valve is useful only in the fœtal state, and its office is to direct the blood of the inferior cava through the *foramen ovale,* an aperture by which, during fœtal life, the two auricles communicate with each other. This aperture closes after birth, leaving an oval depression in the septum of the auricle, termed the *fossa ovalis.*

At the opening of the coronary vein also, a valve is found formed by a semilunar fold of membrane, and which prevents the reflux of blood from the auricle into the vein. There are no valves at the entrance of the superior cava into the right auricle, nor of the pulmonary veins into the left.

The Arteries. The vessels into which the blood is propelled by the action of the heart, and distributed to all parts of the body, are termed arteries. These vessels form two distinct systems, the aortal and the pulmonary; the former connected with the left, the latter with the right ventricle of the heart. The main trunk of the aortal system, which opens into the left ventricle, is called the aorta. It contains scarlet-coloured blood, which it distributes by its ramifications throughout all parts of the system, terminating in minute twigs at the periphery of the body, and in the limbs and internal organs. The main trunk of the pulmonary arterial system, which arises from the right ventricle, is

called the pulmonary artery. It carries dark-coloured or *venous* blood, and its ramifications are distributed throughout the lungs.

Where an artery divides, its branches have an area greater than that of the trunk, and they generally diverge at acute angles. In general, the arterial and venous trunks are distributed together; the larger arteries having an accompanying vein, the smaller ones two. The capacity of the venous system is much greater than that of the arterial.

The arteries frequently inosculate with one another, permitting the blood to pass freely from one branch to another, and these communications increase as the arteries become more distant from the heart. Hall, however, says, that in no instance was he able to detect an anastomosis between the minute or extreme arterial branches. These vessels are nourished by minute arterial branches, distributed through these tunics, and which are termed *vasa vasorum.* They are also supplied with nerves, which are derived principally from the great sympathetic. The structure of these vessels has already been described.

The Veins. The *veins,* which return the blood to the heart from all parts of the body, constitute, like the arteries, two systems; one of which corresponds to the arterial system of the aorta, and conveys dark-coloured or venous blood from the periphery of the body, from the head, trunk, and limbs, and from all the internal organs, to the right auricle of the heart, into which it opens by the two great trunks, called the *venæ cavæ superior* and *inferior.* The other, which corresponds to the pulmonary arterial system, conveys scarlet-coloured or arterial blood from the lungs to the left auricle of the heart, into which it opens by four large trunks, called the pulmonary veins.

The veins have several origins. The most general is from arteries, either directly or through the medium of capillaries. The blood in living animals, and the substances used for injecting the vessels, pass from the arteries to the veins by continuous canals. If the arteries of the pia mater be injected with tallow and vermilion, the veins will be filled with the tallow without the vermilion; the superficial veins in the hand or foot may be injected with quicksilver, from the arteries, facts which prove the continuity of the two kinds of canals. A second origin is from cells, of which in the human body, the *corpora cavernosa* of the penis and clitoris, and the maternal part of the placenta furnish the only examples. In these parts, at least, the veins must be supposed to exercise the function of absorption. A third origin is from sinuses, as from those of the dura mater. A fourth, is from other veins, as in the liver, where the hepatic veins originate in part from the extreme ramifications of the vena portæ.

Anastomoses are not uncommon between the radicles of the

veins, presenting the curious and interesting phenomenon of two currents of blood in the same vessel, flowing in opposite directions.

The veins are very strong and flexible tubes, though possessed of little elasticity. They are furnished with numerous valves, formed by semilunar folds of thin interior tunic, the office of which is to prevent the reflux of the blood. Like the arteries, they are furnished with vasa vasorum, and with nerves derived from the great sympathetic.

The Capillary Vessels. The *capillary system,* which is intermediate between the terminations of the arteries and the origins of the veins, presents two modifications. In one, it consists of canals furnished with proper coats or walls, which carry blood from the extreme arteries into the origins of the veins. But in many parts of the body, the coats of these fine vessels disappear, and the globules of blood find a passage for themselves, in various directions, in the parenchyma of the organs; and these passages at length begin to enlarge, acquire walls, and assume the character of the finest veins. The capillary canals of this species are much smaller than the first, and it is said, permit only a single globule of blood to pass out at a time. They are also subject to great changes, some of them disappearing and closing up, and new ones being formed. The formation of these vessels is caused by the fine arterial canals gradually losing their coats, and becoming confounded with the parenchyma of the organs. The capillary vessels have numerous anastomoses, and they are the theatre of the functions of nutrition, secretion, calorification, hematosis, &c.

The transition from arteries to veins presents different dispositions. Sometimes a fine arterial twig merely bends round and reverses its direction, and is at once converted into a vein. Sometimes these parallel vessels communicate by lateral branches passing transversely from one to the other. But in general, the ultimate arterial branches form numerous ramifications, which inosculate with each other, so as at last to form a delicate network; and from this network originate similar ramifications, which, uniting together form the commencement of the veins, and the fine arteries and veins leading respectively to and from this network, run parallel and almost in contact with each other. In the liver the same capillary network receives twigs both from the hepatic artery, and the vena portæ, and gives origin to the radicles of the hepatic veins, as appears from injections. In the capillary system of the lungs there is a similar disposition. Twigs both from the pulmonary and from the bronchial arteries contribute to the formation of the same capillary network; and branches of no inconsiderable size, of

these two different sorts of vessels are known to communicate together.

The capillary system is divided into two sections or departments, one called the *general*, the other the *pulmonary*. The first of these is intermediate between the ultimate branches of the aorta, and the origins of the venæ cavæ. It is the theatre of nutrition, and secretion, and of the conversion of arterial into venous blood. The second exists only in the lungs, and is intermediate between the pulmonary artery and the pulmonary veins. It is the seat of hematosis, or of the conversion of venous into arterial blood, and may be considered as opposed to the general capillary system, in which the mass of the blood undergoes the opposite changes.

It appears from this, that the lungs have two capillary systems, viz. one connected with their peculiar function, or *respiration;* and another, which is a branch of the general capillary system, and is connected with the *nutrition* of these organs.

Some physiologists do not admit a distinct capillary system. According to Wilbrand, the arteries terminate and are lost in the tissues and organs, and the veins originate anew. Most physiologists, on the contrary, contend for the immediate passage of the arteries into the veins, and Rudolphi asserts that the placenta affords the only exception to this structure.

Hall says that he had never seen an instance of the immediate termination of an artery in a vein. Capillary vessels are generally, if not invariably, interposed. These vessels may be distinguished from the minute arteries and veins, by their retaining a uniform diameter during their continual divisions, conjunctions, and inosculations, while the minute arteries continually subdivide into smaller branches, and the minute veins unite into larger. Another distinguishing character between the minute arteries and the capillaries is, that in the former, the pulsatory movement of the blood is distinctly visible, but in the normal state of the circulation, never extends to the capillaries. These vessels, Hall says, are formed by the subdivision of the ultimate arterial branches into others of equal size with itself, a structure which, by increasing the capacity of the vessels, produces a more diffused and slower circulation. Placed between the minute arteries and veins, they always retain the same diameter, however frequently they may divide, subdivide, unite, anastomose, and even form circles. In fact, they form a complete network of vessels, which constantly retain the same dimensions and character.

In the higher orders of animals, injections readily pass from arteries into veins; although in the invertebrated animals, or at least in many of them, it is said to be impossible to force injections from the former into the latter vessels. Milk injected into an artery, has been seen in the blood of the veins. Even foreign sub-

stances injected into the system of the *vena cava* have been observed in the blood of the aortal system, and even in the fluids secreted from it, and of course must have passed from the pulmonary artery to the pulmonary veins. In one experiment Mayer observed in the blood of the *aorta,* and of the *vena portæ,* milk which he had injected into the jugular vein of a rabbit. In this case the milk had passed not only from the pulmonary artery to the pulmonary veins, but from the arteries to the veins of the intestines, and hence had traversed two capillary circulations.

Such is a brief account of the general structure of the heart and blood-vessels, in the human species, the mammalia, and birds. In another class of animals, the reptiles, a part only of the blood passes through the lungs, to become endued with the arterial principle; these animals being so constituted, that the aeration of a portion of the blood is sufficient for the renovation of the whole mass. In the reptiles, therefore, it is not necessary that the two kinds of blood should be kept separate. Indeed, if they were so, the renovated portion could not impart its animating influence to the other. Hence, these animals have only a single heart, consisting of one ventricle, and one or two auricles. The auricle receives both arterial blood from the lungs, and venous blood from all parts of the body; and in its cavity these two kinds of blood are mixed together. From the ventricle arises a single arterial trunk, which divides into two branches, one of which carries a portion of the blood to the lungs, to be subjected to respiration; the other distributes the remaining portion to all parts of the body.

In the other classes of animals, the two kinds of blood are not mixed together, but remain distinct; and, of course, one and the same heart is not sufficient to circulate both. In these classes of animals, comprehending the worms, the mollusca, the crustacea, and fishes, the organs of the circulation present different dispositions. Worms have no heart; and the circulation, which consists in the passage of the blood from the organs of respiration to all parts of the animal, and its return to these organs again, is carried on exclusively by vessels. In the crustacea, and most of the mollusca, there is a single heart only, but it is designed to circulate only *arterial* blood. Its office is limited to the conveying of arterial blood to the various parts of the body; and this blood after its conversion to venous blood in the different organs, is returned to the organs of respiration by *vessels.* These animals, therefore, possess an *arterial* heart. In the cephalopodes there are three hearts, two venous and one aortic.

In fishes also there exists only a single heart; but this is not designed to circulate both kinds of blood, as in the reptiles, nor arterial blood alone, as in the crustaceous and some of the molluscous animals. Its office is to propel the venous blood to the

gills, while the arterial blood is conveyed from these organs to all parts of the system, not by another heart, but wholly by *vessels.* Fishes, therefore, have properly only a *venous* heart. Their aorta is a vessel formed by arteries which proceed from the gills.

The Circulation.

It has already been observed, that the heart is a double organ, being composed of two distinct hearts united together. Each of these is the organ of a distinct circulation. One of them, viz. the arterial heart, is the agent of the greater, or the *general* circulation; the other, or the venous heart, is the organ of the lesser, or the pulmonary. In the general circulation, in which the course of the blood forms a larger circle, arterial blood is projected from the arterial heart, through the aorta and its branches, to all parts of the body, and, having lost its arterial character in the various organs, is returned as venous blood, to the pulmonary or venous heart. The venous heart is the origin or point of departure of the lesser or pulmonary circulation, which forms a much smaller circle than the aortic. It consists in the passage of the venous blood through the lungs, where it loses its venous character by the influence of respiration; and in its return from the lungs, as arterial blood, to the arterial or aortic heart.

Beginning at any given point in the circulation, as e. g. at the auricle of the pulmonary or venous heart, the course of the blood is as follows. The pulmonary auricle receives the venous blood on its return from all parts of the system. From the auricle it passes into the corresponding ventricle, by the contraction of which it is projected into the pulmonary artery, and by the ramifications of this vessel is conveyed to the capillary system of the lungs. Here it loses its venous character, and is converted into arterial blood. It is then taken up by the pulmonary veins, and conveyed to the auricle of the arterial heart, and thence into the corresponding ventricle, by the contraction of which it is projected into the aorta, and by the ramifications of this vessel distributed to all parts of the system. In the capillary vessels of these it loses its arterial character, and then passes into another system of vessels, the veins, by which it is returned as venous blood to the auricle of the pulmonary heart, from which its course was supposed to commence.

It appears from this, that neither circulation is quite complete; for, in neither does the blood return to the same point from which its course commenced. In order to arrive at this point, wherever it be assumed, the blood must pass the round of both circulations, arterial and pulmonary, and undergo both of the changes which are effected in the capillary systems of the two, i. e. the change

from arterial to venous, and that from venous to arterial blood. It appears, then, that the two parts of which the heart is composed are so related to each other, that the ventricle of one forms the commencement, and the auricle of the other the termination, of a distinct circulation. The heart has the lungs between its right ventricle and its left auricle; and all the organs of the body, including the lungs and the heart itself, between its left ventricle and its right auricle. The right ventricle and the left auricle, therefore, are the two extremes, between which is comprehended the pulmonary or lesser circulation; while the left ventricle and the right auricle bound the arterial or the greater circulation.

Besides this division of the circulation into aortal and pulmonary, or greater and lesser, another was proposed by Bichat, founded on the qualities of the blood, and the changes which it undergoes in the lungs, and the general capillary system. Bichat divides the circulation into arterial and venous, or the circulation of red, and that of black blood. In the first, the blood passes from the lungs to all parts of the body; in the second, it returns from all parts of the body to the lungs again. According to this view, the circulation may be reduced to two phenomena, viz. the passage of the blood from the capillaries of the lungs where it assumes its arterial properties, to the general capillary system where it furnishes the elements of nutrition and of the secretions, and acts as the universal excitant of all the organs; and, secondly, the passage of the blood from the general capillary system to the pulmonary capillaries, where the properties of the vital fluid are renovated by respiration. In this view, the two capillary systems, the general and the pulmonary, are the points of departure of the two circulations, instead of the aortal and pulmonary sides of the heart.

The circulation of red blood commences in the capillary system of the lungs, where the blood acquires the peculiar characters which distinguish arterial blood. From the capillary system of the lungs it passes into the pulmonary veins, which convey it into the left auricle, or that of the arterial heart. From this it passes into the corresponding ventricle, which projects it into the aortal system. Through this it is distributed to the general capillary system, which may be considered as the termination of the circulation of red or arterial blood. In this, then, the arterial blood is constantly passing from the capillary system of the lungs, to the general capillary system; and, in its passage, it is transmitted through the arterial heart, or what is commonly called the left side of the heart. The whole of the left side of the heart, therefore, belongs to the circulation of arterial blood.

The circulation of the black or venous blood, commences where the former terminated, i. e. in the general capillary system.

Here the blood is converted from arterial into venous, from scarlet to purple-coloured blood. From the general capillary system it passes into the veins, which convey it to the pulmonary or venous heart. From this it is distributed by the pulmonary artery, to the capillary system of the lungs, which is the termination of the circulation of venous blood. This circulation, then, consists in the passage of venous blood, from the general capillary system to that of the lungs, in the course of which it passes through the pulmonary or venous heart. The whole of this side of the heart, therefore, belongs to the circulation of venous blood. Each of these circulations begins with veins, and terminates with arteries, and each of them, in its course passes through both cavities of one side of the heart. Each of them consists of two segments of circles of unequal size; the larger being a moiety of the general or aortal circulation, the smaller, a division of the pulmonary. The circulation of red or arterial blood, consists of the venous part of the pulmonary, and of the arterial part of the general circulation; and the circulation of venous, or purple blood, consists of the venous segment of the aortal or general circulation, and of the arterial segment of the pulmonary.

The two circulations are entirely independent of each other, except at their origins and terminations, the two capillary systems, where the arterial and venous blood are reciprocally transformed into each other; and they intersect each other at the heart, through which they both pass, yet without communicating together.

In the circulation of red, or arterial blood, the vital fluid is sent to the general capillaries, and traverses all the organs, furnishing in its passage the elements of nutrition, and of the secretions. It also communicates to all the organs a peculiar species of vital impulse, or excitation, indispensable to life and to the functions of the organs. A part of the arterial blood remains in the organs, to replace the materials removed by vital decomposition; another part is expended in the secreted fluids, and passes into the canals belonging to this function in the different secretory organs. Of course, a part only, and perhaps but a small part of the blood, returns to the heart, robbed of its vital and nutritious principles, and presenting the characters of venous blood. The first impulse of the blood in this circulation, is received in the capillary vessels of the lungs, but its principal moving power is the left ventricle of the heart.

In the circulation of black or venous blood, this fluid passes from the general capillary system to that of the lungs, in order to be renovated and converted again into arterial blood by respiration. In its passage to the pulmonary heart, it is reinforced by the addition of a considerable quantity of chyle and lymph, which are on their way to the lungs, to be converted into blood

by respiration. These two fluids, the chyle and the lymph, are gathered up and conveyed into the blood by an order of vessels called absorbent. These vessels, collecting the materials of renovation from the organs, by vital decomposition, and from all the free surfaces of the body, internal and external, convey them by two principal trunks into the great veins near the heart. These materials are unfit for the purposes of the economy, some of them by defect of animalization, others, perhaps, by an excess of it. They are, therefore, blended together, and mixed with the venous blood, with which they are transmitted through the lungs, where the whole compound fluid is converted by respiration into arterial blood. The venous blood appears to owe its principal characters to an excess of carbonic acid, and, perhaps, to the loss of oxygen, expended in nutrition and the secretions. In asphyxia from carbonic acid, the blood is said to be much darker than in asphyxia from other causes. The motion of the venous blood is first impressed by the action of the general capillaries, which forces the vital fluid into the radicles of the veins, where it clears the first set of valves. These sustain the column of blood, and prevent its retrograding, when the veins, excited by the stimulus of the blood, contract upon it, and force it beyond the next series of valves. When it reaches the pulmonary heart, it receives a new impulse by the contraction of the right ventricle.

The passage of the blood through the two capillary systems, may be considered as constituting a distinct circulation, which may be termed the *capillary*.

This may be divided into two kinds, viz. the *general*, and the *pulmonary* capillary circulation. In the former, the blood furnishes the organs with the materials of nutrition, and of the secretions; caloric is evolved, the blood becomes charged with carbonic acid, and perhaps loses some of the oxygen it had acquired in respiration, and is converted from arterial into venous blood.

The capillary circulation of the lungs may be considered as opposed to the former. It has for its object, the renovation of the blood, or its conversion from venous to arterial, by respira tion; an effect which seems to be produced by the loss of carbonic acid, and the acquisition of oxygen.

The capillary system possesses no central organ of impulsion like the two others, but depends on the vital contractility of the minute vessels which execute it; and it does not present the same regularity as the cardiac circulation. In the normal state, the general sum of its activity remains nearly the same; since the same quantity of blood must traverse the capillary system in a given time. But the activity of particular parts of it may be much increased or diminished. By increasing it in one place we may lessen it

in another, and *vice versâ;* a principle on which depends the effect of counter-irritation. The capillary circulation survives the cardiac, and is the last to cease at death.

Admitting the existence of the capillary system, animals may be said to possess two circulatory systems; one a *peripheral,* which constitutes a circle, the other, a *central,* which forms the radii of this. The lower we descend in the zoological scale, the more the peripheral or capillary predominates; and the higher we ascend, the more does the central or cardiac. Hence, the more easy re-establishment of the circulation in the lower than in the higher animals, after the ligature of large arteries; the circulation being then maintained by the numerous anastomoses of the peripheral system.

Mechanism of the Circulation.

The motion of the blood is maintained principally by the action of the heart. This organ is endued with great irritability, in consequence of which it contracts with great force upon the blood, which flows into it from the veins, and propels it into the mouths of the great arteries, which communicate with its ventricles.

The action of the heart consists of an alternate contraction and dilatation, or systole and diastole, of the auricles and ventricles. When the auricles receive the blood returned from the general circulation and the lungs, by the venæ cavæ and the pulmonary veins, they contract upon it and force it into the ventricles, which dilate at the same moment to receive it; and immediately afterwards, when the distended ventricles are contracting to force the blood into the aorta and the pulmonary artery, the auricles dilate in order to receive a new supply from the veins. Hence the contraction of the auricles and the dilatation of the ventricles, take place at the same time, and *vice versâ.* The two auricles contract and dilate simultaneously, and the same is true of the two ventricles. This is probably owing to the fact that the two auricles have a common muscular septum, so that one cannot contract without the other; a structure which exists also in the ventricles; while the auricles are connected to the ventricles only by cellular tissue, vessels, and nerves.

When the auricles contract, the blood expelled by their action is thrown back partly upon the veins, producing, in some cases, a venous pulse; but the greater part of it enters the ventricles, which spontaneously dilate to receive it. A pulse in the jugular veins is sometimes perceptible in persons of spare habits, and in morbid affections of the lungs, owing to a reflux of blood into these veins at the time of the contraction of the right ventricle.

In some cases this reflux extends to the veins of the liver, producing an engorgement of this organ. So, where there is an obstacle to the passage of the blood into the aorta, there is sometimes a reflux into the pulmonary veins, by which the lungs become engorged.

The experiments of Hope, confirmed by those of Bouillaud, appear to have established the following facts respecting the rhythm of the heart's action.

The first motion of the heart which succeeds the interval of repose, is the *systole* of the auricles. This movement consists in a slight contraction, which is most conspicuous in the auricular appendage, and which is propagated rapidly by a kind of vermicular motion to the ventricle. The motion, though rapid, is not so quick but that it can be easily followed by the eye.

The *systole* of the ventricle which succeeds, commences suddenly, and consists in a sudden and energetic jerking movement, accompanied by a depression of the centre or body of the ventricle, and the elevation and impulse of its apex against the side. The shock of the heart against the ribs, and the pulsations of the arteries near the heart, are simultaneous with the ventricular systole. In the arteries more distant from the heart, the pulse is not exactly synchronous with the systole, but follows it at a scarcely appreciable interval.

The *systole* is succeeded by the *diastole* of the ventricles, which is an instantaneous motion of expansion, accompanied with an influx of blood into the ventricles, while the apex of the heart collapses and retires from the side.

To the diastole succeeds the interval of rest, in which the ventricles remain quiescent and in a state of fulness, but not distention, until again excited by the auricular contraction, which introduces anew the same series of movements.

A complete revolution of these movements occupies, in an adult, about the space of a second. Of this time the ventricular systole occupies about one half; the diastole about one-fourth, or a little more; the interval of rest one-fourth, or rather less. The auricular systole occurs during the latter part of the period of repose, and occupies of course only about one-eighth of a beat. As the contraction of the ventricles occupies only one-half of the time of the whole beat, it appears that the ventricles enjoy twelve hours rest out of each twenty-four. This is true, however, only on the supposition that the diastole is a state of repose. Hope estimates the interval of rest enjoyed by the ventricles at only six hours out of the twenty-four, falling, in each beat, between the diastole of the ventricles and the next auricular systole. The repose of the auricles he estimates at about the same; for though the systole of the auricles occupies only about one-eighth of a

whole beat, the remaining seven-eighths, Hope remarks, is not devoted to repose; for during most of this time the auricle is in a state of greater or less distention, which is not repose.

The action of the auricles is gentle, and is sometimes repeated before the contraction of the ventricles takes place. The extent of the auricular contraction is very inconsiderable, says Hope, not amounting probably to one-third of its volume, and of course the quantity of blood thrown by it into the ventricle is but small; yet sufficient, as the ventricle is already full in consequence of its diastole, to bring it to a degree of distention necessary to excite it to contraction. It is further to be observed, that the auricles contract twice or more for every ventricular systole. In a rabbit, Hope saw the auricle make two or three contractions without exciting the ventricle, when a fourth, of about the same degree of energy, caused the heart to start up with the usual appearances of the ventricular systole. The auricles expel but a small portion of their contents at a time, and are constantly full; their motions ranging between fulness and distention. In small animals, as the frog, the ventricles expel the whole of their blood, as appears by their becoming pale during the systole; but in large animals, as the ass, they do not appear to expel the whole, to judge from their diminution of volume. According to some physiologists, during the contraction of the auricles, one of the tricuspid valves closes the orifice of the pulmonary artery, and one of the bicuspid that of the aorta, so as to prevent the entrance of the blood into these vessels, during the dilatation of the ventricles.

The right auricle has more fleshy columns than the left, to enable it more thoroughly to blend together the chyle, the lymph, and the venous blood.

During the systole of the ventricles, the tissue of the heart hardens and shortens itself, and is displaced a little; and its apex, curling upwards, strikes the left wall of the chest, between the sixth and seventh ribs. This phenomenon has been referred to the impulse which the aorta and pulmonary artery receive from the wave of blood projected into them, which displaces them a little, and produces a reaction upon the heart, by which the point of the organ is pushed forward and to the left. The dilatation of the auricles also, which takes place during the contraction of the ventricles, must contribute to carry the latter forwards. It appears, however, that these circumstances are not necessary to produce this effect; for if the heart of an animal recently killed, be placed, while yet palpitating, upon a table, the apex continues to be tilted up by each contraction of the ventricles. Hope explains this phenomenon in the following manner. During the state of relaxation, the heart lies collapsed and flattened, with a large extent of its inferior surface resting upon the table. On

contracting, it starts up, and assuming a more globular form, is supported by a much smaller surface. Hence the apex is elevated, and the more so, because the base, from its greater weight, is the less movable part. According to Hope, the mechanism of this action is very similar in the living subject. The auricles, especially the left, are attached to the posterior part of the base, and the aorta and pulmonary artery spring from its anterior part. The auricles being in a state of distention during the systole of the ventricles, form an unyielding fulcrum under the ventricles; the fibres of which contracting towards the aorta and pulmonary artery in front, draw up the rounded body of the heart upon the auricles behind. In this view of the phenomenon, the auricles represent the fulcrum of the lever, the apex of the heart its long arm, while the moving power is applied at the aorta and pulmonary artery.

The walls of the left ventricle are thicker and stronger than those of the right, because it has a greater distance to project the blood; and, according to Berthold, the right ventricle has a greater capacity than the left, because the venous system, to which it belongs, is more capacious than the arterial. By the systole of the ventricles, the blood is projected with great force and velocity into the aorta and pulmonary artery, and, through these canals, distributed throughout the general system and the lungs. It is then taken up by the radicles of the corresponding veins, and returned by the trunks of these vessels to the auricles of the heart. The motion of the blood is more rapid, as the arteries are larger and nearer the heart. Its velocity gradually diminishes as the arterial canals become smaller, and recede farther from the heart, as appears from the feeble jets of blood emitted by the small arteries. In arteries of a certain degree of minuteness the jets disappear; a fact which proves that the force of the heart is much lessened in these remote vessels. This gradual retardation of the velocity of the blood is owing partly to the increasing resistance which this fluid has to encounter in its passage through the arterial tubes, from friction and other causes, and partly to the increasing capacity of the vessels as they become more distant from the heart. In the veins, on the other hand, the blood moves with a constantly accelerated velocity, towards the heart.

According to Hall, the natural circulation is rapid and slightly pulsatory in the minute arteries, but in the true capillaries and venous system, slow and equable. But if the circulation be in the slightest degree impeded, the pulsatory motion at each contraction of the heart becomes very manifest, and is visible in all the three systems of vessels, arterial, capillary, and venous. In the arteries, the motion of the globules is alternately more and less rapid at each systole and diastole of the heart. In the capil-

laries and veins, the flow of the blood is often completely arrested during the diastole, and again proceeds by a pulsatory movement during the systole of the heart.

The course of the blood in the arteries is an intermittent one. It is alternately more or less rapid; more so during the systole of the heart, because then the blood moves under the influence of the most powerful of the moving forces; less rapid during the diastole, because it then moves only under the contractile reaction of the arteries. In the first moment it flows by jets, which coincide with the contraction of the ventricles, and which are greater as the artery is nearer the heart. In the second, it flows from an open vessel in a continued stream in consequence of the reaction of the arterial walls. The blood which flows from an artery between the jets, issues out by the elasticity of the arterial tunics.

The motion of the blood in the small vessels is much promoted by a high temperature. Hales found that hot water injected into the mesenteric artery returned by the corresponding vein, with a velocity thirty-two times as great as that of a lukewarm fluid, injected into the same vessel. When he injected cold water, the velocity of its motion was only one-eighteenth as great as that of the same volume of fluid of a medium temperature, under the same pressure. For this reason, during very hot weather, a greater quantity of blood is constantly passing through the vessels, and the exhalations from the skin and lungs, are much increased. Hence, as Magendie observes, in persons affected with organic disease of the heart, cold damp weather is sure to bring on fits of suffocation, as well as infiltration and swelling of the lower extremities. If now the temperature of the weather rises, even if the change be small, the circulation immediately becomes freer, and the symptoms above mentioned disappear.

It has been ascertained that the column of blood passing through a vessel moves with different velocities in the central and the exterior parts of the current.

Upon examining the motion of the blood in an artery under the microscope, if the coats of the vessels are thin enough to admit of the passage of light, it will be seen that the globules move with the greatest rapidity in the axis of the vessel, and the velocity gradually diminishes in passing from the centre to the periphery of the canal. It appears also that, contiguous to the internal surface of the vessel, there is a space, about one-tenth or one-eighth of the diameter of the tube in breadth, which is filled with the serum of the blood, and in which this fluid is nearly motionless; for when red globules leave the central current, as they approach this external stratum, their motion becomes less rapid, and if they get entangled in it, almost wholly ceases; if they come into contact with the sides of the vessel, they become stationary. In minute vessels the influence of this motionless

stratum of serum, and of these different degrees of velocity of the current, will be very considerable; for a greater relative quantity of the blood will be motionless, and the diameter of the central moving column will be extremely small. If the calibre of the vessel be very small, the central current will be reduced to a mere thread, and in tubes still more minute, fluids can scarcely move at all.

It is a very curious fact, noticed by Magendie, that the viscidity of the blood, instead of being unfavourable to its passage through the capillary vessels, is an indispensable condition to its motion in these minute tubes. If it be deprived of this quality, it becomes unfit to circulate in these living canals. A certain degree of viscidity indeed has been found to promote the passage of liquids through inorganic capillary tubes. Very pure water, e. g. will pass either not at all, or with great difficulty through very minute tubes, but if a little albumen be added to it, it traverses with ease the same canals.

Attempts have been made to compute the force with which the ventricles of the heart contract. It has been found that the action of the heart is capable of supporting in a tube connected with the arteries, a column of blood eight feet high, producing a pressure of about four pounds to the square inch on the inner surface of the arterial coats: adding to this, the inertia of the injected fluid, and of the blood already contained in the artery, as also the yielding of the coats of the vessel, the force with which the heart acts may be estimated at six pounds the square inch. Now the left ventricle when distended has about ten square inches of internal surface, and hence the whole force exerted by it may be about sixty pounds. This corresponds nearly with the calculation of Hales, who estimated the force exerted by the left ventricle of a horse, in propelling the blood, at 113.22 pounds, and that which is exerted by the left ventricle of a man's heart, at 51.5 pounds. According to Lepelletier, the systole of the left ventricle overcomes the whole pressure of the atmosphere upon the body, equal to 35,000 or 40,000 pounds.* The resistance which the systole of the heart has to overcome, arises from the inertia of the mass of blood which it propels, and the friction of this fluid against the walls of the vessels, through which it passes.

Poiseuille ascertained by experiment that the pressure acting upon the inner surface of the arteries of an animal, is the same in every part of the system. There is an exact equality of pressure in all parts of the arterial system, whatever may be the difference of diameter in the arteries, or in their distance from the

* Is not the effect partly owing to the superior energy of contraction of the left ventricle?

heart. He also discovered the remarkable fact, that his hæmadynamometer indicated the same arterial pressure in a horse and dog, showing that a heart which weighs only three or four ounces, exerts the same amount of pressure on the walls of the vessels, as one which weighs six or seven pounds. In the veins the pressure is much less than in the arteries, in consequence of their superior capacity. The pressure diminishes during inspiration and increases during respiration.

The injection of water into the veins, weakens the contractile energy of the left ventricle, and the general pressure of the blood throughout the whole vascular system. Hence the beneficial effects of aqueous drinks in febrile diseases.

When an artery is tied, the pressure of the blood which is removed from its internal surface, is distributed throughout the remainder of the arterial system. The force of the contractions of the left ventricle being resisted by the ligature, is divided among the other vascular tubes which remain open, and increases the pressure of the blood in every part of the arterial system. Hence the amputation of one of the extremities, which diminishes very considerably the circle of the circulation, is followed by increased pressure and tension of the whole arterial system. The effect is partly to be ascribed to the diminished surface on which the force of the left ventricle acts, and partly to the relative increase of the volume of the blood, compared with the diminished capacity of the vascular system.

Poiseuille found that pain increases the internal pressure of the vessels, probably by augmenting the energy of the contractions of the heart. I have known an apoplectic affection occur in a young lady immediately after the extirpation of a small tumour from the neck. The operation was borne with the utmost patience and tranquillity, but as soon as it was completed, she began to yawn in a very extraordinary manner, and soon became speechless, and nearly insensible. This state continued about two days, when it terminated in death. In this case the pain of the operation, and the effort to suppress any manifestation of it, may be supposed to have increased the vascular pressure to such a degree, that the vessels of the brain could not sustain it. The father of this lady, a learned president of one of our most distinguished universities, died of apoplexy.

The whole quantity of the blood in the body of an adult, is estimated at between thirty and forty pounds, and this, it is computed, performs more than five hundred and fifty revolutions through the body every twenty-four hours. A complete revolution of the blood, it is estimated, is accomplished in about three minutes. The contractions of the ventricles take place at equal intervals, and in adults from seventy to seventy-five times in a minute. In new-born infants, the heart contracts about one hun-

dred and forty times in a minute, a rate which gradually diminishes until the period of adult age. In old age, the contractions of the heart diminish in frequency, the pulse not exceeding sixty in a minute.

Sounds of the Heart.

Upon applying the ear to the region of the heart, a double sound, consisting of two successive sounds followed by an interval of silence, is distinctly heard. This double sound, which has been compared to the ticking of a watch, will be found to coincide with the beating of the heart and the pulsation of the arteries, and of course to recur with the same frequency. The first sound is duller and more prolonged than the second, in which it terminates without any appreciable interval. The second, which is shorter, clearer, and more sonorous than the first, resembles the flapping of a bellows' valve; or the sound of a dog lapping water, or that produced by gently striking the surface of a fluid with the flat of the hand. This sound succeeds the first so rapidly as almost to be confounded with it. The interval of silence then follows, the length of which will depend on the slowness or infrequency of the heart's contraction. This interval is interrupted by the first sound, which commences the series anew.

This double sound is owing to the action of the heart beyond all question, but as to the mechanism of it, many opinions have been entertained by physiologists, and the subject is still in an unsettled state. It is ascertained, however, that the first or dull sound occurs during the ventricular systole. It is synchronous with the impulse of the heart against the side and with the pulse; and in the experiments on animals, has been observed to occur at the moment the ventricle was seen to contract. Experiment has also determined that the second or clearer flapping sound occurs during the diastole of the ventricles. The most prominent opinions as to the causes of these sounds are the following.

1st. That which refers them to the contraction and *active* dilatation of the ventricles. It is well known that muscular contraction produces sound. If the fist be clenched and applied to the ear, a sound is heard similar to that of a distant carriage rolling rapidly along. This obscure rumbling or roaring noise is composed of a series of sounds, following one another in rapid succession; and it immediately ceases when the muscular contraction is discontinued. If the contraction becomes more forcible, the vibrations which constitute the sound become more frequent; in the opposite hypothesis, less so; or if the ear be rested upon a cushion, and the person clenches the jaws forcibly, as by biting the knot in a handkerchief, the same result is obtained. The introduction of the point of the finger into the ear also gives rise

to this sound. Muscular contraction, however, is not in all cases productive of this sound. This is true for the most part of the spasm of tetanus.

The opinion that the sounds of the heart are owing to a similar cause is untenable, for they are entirely unlike in their character, and the former are vastly louder than any muscular sounds; besides all which, the sounds of the heart are generally louder, as Hope remarks, in direct proportion as the ventricular walls are thinner.

A second opinion, which is that of Dr. Hope, ascribes these sounds to the impulse given to the molecules of the blood, by the contraction of the ventricles. This impulse is first given to the particles of blood in contact with the ventricles, and is propagated from particle to particle through the mass of the fluid, the collision between them producing sound. The irregularity of the internal surface of the ventricles, occasioned by the columnæ carneæ, seems calculated to favour the production of sound; for the external stratum of blood, which is entangled as it were in the sinuosities of the columnæ, is thrown into innumerable conflicting currents by the contraction of the ventricles. Hence the collision of the particles is more extensive and violent, than if it were occasioned by a simple direct impulse. The central mass at the same time is tending towards the mouths of the aorta and pulmonary artery; and as it is composed of a multitude of conflicting currents, reflected on all sides from the walls of the ventricles, and converging towards these orifices, the collision thus produced in the molecules of the blood occasions the sound.

The second sound, or that of the diastole of the ventricles, is occasioned, as Hope supposes, by the sudden reaction of the walls of the ventricles upon the blood at the completion of the diastole. The particles of this fluid, which shoots with great velocity from the auricles into the ventricles, are suddenly arrested in their course by the abrupt termination of the ventricular diastole, and the reaction of the ventricles produces the sound. The auricles do not contribute to either sound, nor indeed, according to Hope, do the auricular contractions produce any sound whatever.

On this theory Bouillaud remarks, that if it were well founded, these sounds ought to continue, or at least not wholly disappear, in indurations or other lesions of the valves. But in fact, according to Bouillaud, these lesions, especially indurations of various kinds of the valves, put a complete, or nearly complete stop to the normal sounds of the heart, and give rise to certain accidental sounds, known under the name of the bellows or rasping sound, &c.

A third opinion is that of Rouanet and Bouillaud, which ex-

plains the sounds of the heart by the action of the valves, on the principle in which sound is produced by the play of the valves in machinery.

The first sound, or that of the systole of the ventricles, is supposed to be caused, 1. By the sudden and energetic closure of the auriculo-ventricular valves, which are drawn towards each other by the contraction of the columnæ carneæ, so as to come smartly together. 2. By the sudden depression of the semilunar valves, by the column of blood projected into the aorta and pulmonary artery by the systole of the ventricles.

The second sound, or that of the dilatation of the ventricles, is caused, 1. By the forcible elevation of the sigmoid valves by the wave of blood which the aorta and pulmonary artery forces against them, and the sudden collision of their opposing faces; 2. Sudden depression of the auriculo-ventricular valves, which is produced by the diastole of the ventricles, aided by the contraction of the auricles, propelling the blood into them.

The chief cause of this second sound, is supposed to be the sudden impulse of the column of blood against the aortic and pulmonary valves.

The chief argument in favour of this theory of the sounds of the heart is, that whatever diseases this organ may be affected with, so long as the play of the valves is free and unobstructed, the sounds of the heart undergo no material change; and on the contrary, in all affections of this organ which are accompanied with an impeded or abnormal action of the valves, the natural sounds of the heart are essentially changed, and sometimes wholly disappear, giving place to a variety of morbid sounds, as that of the bellows, rasp, saw, file, &c.

Moving Powers of the Circulation.

Some physiologists, as Harvey, Haller, and Spallanzani, consider the heart as the only moving power of the circulation.

Others, as Hunter, Blumenbach, Soëmmering, Senac, Martini, &c., are of opinion, that besides the propelling force of the heart, a muscular contractility of the arteries, is one of the moving forces of the circulation.

A third class, including Bichat, Weitbrecht, and Darwin, deny that the arteries possess an active power of contracting; but they assume a vital contractility in the capillary vessels, a kind of absorbing and propelling force, which moves the blood in the capillary system, which they consider as removed from the influence of the heart.

There is another class, among whom are Treviranus, Carus, and some others, who ascribe the motion of the blood, chiefly, to a self-moving power existing in the blood itself, while they

consider the heart as only an auxiliary force, and deny all power to the arteries and the capillary vessels.

Another opinion, almost as singular, is that of Burns, who regards the arteries as the principal moving powers of the circulation, while he limits the office of the heart merely to the regular delivery of the blood to the aorta, to be afterwards distributed by the contractions of the arteries to all parts of the system. Burns' opinion is founded on a phenomenon, which he alleges is often observed in patients affected with ossification of the aortal valves. He says that it is a well known fact, that in this disease the heart sometimes contracts twice for each pulsation of the arteries, which he affirms could not happen if the heart propelled the blood through the arterial system by its own unassisted powers. For in that case, the arterial pulsations being the effect of the contractions of the heart, would necessarily, in every instance, exactly synchronize with the latter, and could in no case be either more or less. The phenomenon, he says, may be easily explained, by considering, that when the aortal valves become rigid by ossification, they oppose an obstacle to the free passage of the blood from the heart to the aorta; so that a sufficient quantity of blood is not projected into the artery by a single contraction of the heart, to fill the vessel; and the latter, consequently, does not react upon the blood, until it receives an additional supply by a second contraction of the heart.

These opinions we shall not stop to examine, but shall proceed to consider the functions of the different parts of the circulatory apparatus.

Functions of the Heart. The heart is the principal moving power of the circulation; a doctrine which rests on many facts and considerations. One of these is the astonishing irritability of the heart. When this organ is removed from the thorax of a living animal, as, e. g. a frog, and put into warm water, it will continue to contract and dilate with great energy, throwing jets of the fluid to some distance for a considerable time. It even exerts this self-moving power when empty, and placed in a vacuum, so that its action is independent of the contact of air and blood.* In some animals, particularly in some of the reptiles and fishes, the heart retains this power of contracting some time after death. The heart of a snake has responded to very active irritation, four days after the death of the animal. Harvey states that if the heart of an eel, and that of certain fishes, be removed from the

* An old chronicle, purporting to be a contemporary account of the murder of James I. of Scotland, in describing the execution of one of the conspirators, relates that "they boweld and quarterd him all quyke, and drewe out his harte of his body; the which harte lepe thrise more than a fote of heghte, after hit was drawen owte of his body."

thorax and cut into pieces, the separate parts will alternately contract, and become relaxed. The heart of a sturgeon was cut out and laid on the ground, and after it ceased to beat was blown up, in order to be dried. It was then hung up, when it began to move again, and continued to pulsate regularly, though more slowly, for ten hours; and it even continued to contract when the auricles had become so dry as to *rustle with the motion.** Mr. Swan relates, that after tying the principal arteries of a puppy, he removed the heart and lungs, and placed them on a table exposed to the air, and the heart continued to pulsate *for several days!* Mayo states, that if the heart be taken from the body of an animal immediately after death, and the blood be carefully washed from its internal surface, or, if the auricular portion be separated from the ventricles by a clean section, the alternate states of action and relaxation continue to recur as before; and for a short period, no stimulus seems to be required to excite it to contract. The alternation of action and repose, Mayo remarks, seems to be natural to its irritable fibre, or to result immediately from its structure.

Nothing of this kind is observed in the arteries. They never undergo the alternate contractions and dilatations which are observed in the heart taken from a living animal; but they are uniformly found contracted upon themselves. Nor do irritations applied to them excite them to contraction after death. If the finger be inserted into the open aorta, it does not feel itself compressed by the contraction of the vessel, as it does when thrust into the heart.

If an arm of a dead body be cut off, and immersed some time in a warm bath to make it pliable, and a small tube be then fixed by one extremity in the brachial artery, and by the other in the open carotid of a large living dog, the heart of the animal will instantly drive blood into the lifeless arm, and produce a feeble pulsation in the artery. So if several inches of an artery be cut out, and the continuity of the canal be re-established by a metallic tube, the portion of the artery beyond the tube will pulsate just as if the vessel had remained entire. Bichat observes, that if the arteries give rise to the pulse by their own powers of contraction, there ought to be a defect or irregularity in the arterial pulsations below an aneurismal tumour; since the arterial texture being altered and partly destroyed, it must necessarily lose its living powers, and consequently its vital contractility. Bichat further observes, that the jets of blood from an open artery, correspond with the dilatation of these vessels, and the subsiding of the jets with their contraction; which is exactly the reverse of what we should expect, if the pulsations were occasioned by the action of the arteries

* Mitchell, Am. Journ. Med. Scien. No. 13.

themselves. On the whole, there can be no doubt, that the pulse is occasioned by the systole of the heart, and not by the action of the arteries themselves. The pulse, in all parts of the body, is exactly synchronous with the systole of the ventricles.

According to Dr. Young, the velocity of the pulsations is sixteen feet in a second, which would diffuse them simultaneously throughout every part of the system. The pulse seems to be caused, not by the dilatation of the arteries, but by a slight movement of locomotion, or vibration, occasioned by the stroke of the ventricles and simultaneous with it, followed by reaction of the arterial coats upon the column of blood. This occupies the interval between the pulsations. Even when ossified and incapable of being dilated, it is said that they still pulsate. Sometimes the aorta forms a long bony tube, yet the pulse is not obliterated. No pulse exists in animals destitute of a heart.

Functions of the Arteries. The only power which the arteries exert in the circulation, according to Bichat, is the physical property of elasticity or contractility of tissue. In his view of the circulation, the power of the heart projects the blood into the arteries, which at first yield, though very little, to the impulse; but, as the blood advances farther on in the arterial system, the part of the latter nearest the heart, which was first dilated, being relieved of the distention, contracts by its elasticity upon the decreasing column of blood. In this view, the contractile power of the arteries merely serves the purpose of adapting their capacity to the volume of their contents, and, in short, of keeping the arteries constantly full, whatever may be the quantity of blood which they contain. And if we keep in mind the fact, that the arteries, notwithstanding the perpetually varying quantity of their blood, are constantly full, it is easy to conceive that the contraction of the left ventricle, forcing an additional quantity of blood into them, will be felt, at the instant it takes place, throughout the whole arterial system; and that a quantity of blood, equal to that which is propelled into the aorta by each contraction of the left ventricle, will be removed by the same stroke from the further extremity of the arterial system. If the arteries of a dead body be injected with water, and a syringe filled with the same fluid be fixed in the aorta, at the moment the piston of the syringe is pressed down, the water will spirt out of any artery that happens to be open, no matter how remote it may be from the propelling force. In this view, the contraction of the arteries contributes not a particle of power to the circulation, but merely serves to keep the arterial tubes constantly full, by adapting their capacity to the volume of their contents.

Many facts, however, are inconsistent with this doctrine, and tend to prove that the arteries are endued, not merely with the physical property of *elasticity*, but with a *vital* power of *con-*

tractility, by which they contribute to the sum of the moving forces of the circulation.

1. If the carotid artery of a living animal be laid bare for a few inches, and two ligatures be applied to it at some distance from each other, on making a small incision into the artery between the ligatures, the blood will immediately spirt out with considerable force, and the artery become much contracted. As, in this experiment, the force of the heart is intercepted by the lower ligature, the blood must be forced out of the artery by its own contractile power. If the experiment be performed after death, the blood, instead of spirting out to some distance, will flow out with little or no jet.

Magendie compressed with his fingers the crural artery, in a dog, and saw it contract below the pressure, so as to expel from its cavity all the blood it contained.

2. In hemorrhage, the bleeding arteries contract in proportion to the loss of blood; but if the hemorrhage prove fatal, the same vessels return to their original dimensions. Their contraction, in the first instance, is evidently not owing to elasticity, but must be of a vital character, because, after death it ceases, and the arteries become enlarged, and resume their original diameters.

3. Arteries may be influenced by stimulants applied to their nerves. Philip found that the motion of the blood, in the capillary system, was influenced by stimulants applied to the brain. But Sir E. Home ascertained that even the large arteries were capable of being excited, by irritating the nerves which supplied them. He separated by a probe the par vagum, and the sympathetic nerve, from the carotid artery, in dogs and rabbits; and then, touching these nerves with caustic alkali, in one minute and a half he observed the pulsations of the artery gradually to increase, and in two minutes, to become still stronger. In another experiment he wrapped the wrist of one man in ice, and enveloped that of another in cloths dipped in hot water; in consequence of which, in the first individual, the pulse in the wrist operated on, became stronger than that of the opposite wrist; and in the second, weaker.

4. The shrinking of arteries, from exposure to the air, demonstrates a power of contraction in them different from mere elasticity, and which must be of a vital character. Dr. Parry found that the artery of a living animal, if exposed to the air, would sometimes contract in a few minutes to a great extent; and in some instances, only a single fibre of the artery was affected, narrowing the channel of the vessel, as if a string were tied round it.

5. Hoffman observes, that in paralytic limbs, there is in many instances, no pulse, although the power of the heart is unimpair-

ed; and, according to Martini, Nassius relates the case of a man, who died in a fit of syncope, in which a very sensible pulsation of the arteries continued a quarter of an hour after the motion of the heart was entirely extinct. In paraplegia, I have known an almost complete suspension, not only of the capillary circulation, but even of that in the large veins, below the seat of the lesion in the spine. Just *below* the line, dividing the healthy from the paralysed part, it was impossible to obtain blood by cupping; although, just *above* this line, blood escaped freely from the incisions of the scarificator. Some of the cutaneous veins of the thigh were very large and prominent, and apparently distended with a dark blood. Yet upon plunging a lancet into one of them of the size of a goosequill, only a single drop of very black blood escaped from the puncture. Here a part of the vascular system was absolutely paralysed, together with the powers of sensation and motion, by a lesion of the spine, and the blood was almost motionless in the vessels of the affected part, though the powers of the heart were not essentially impaired. Why was not the blood propelled through these vessels by the *vis a tergo?*

6. A fact mentioned by Laennec, and which has probably been observed by many other physicians, is worthy of notice in this place. This eminent pathologist asserts, that in diseases of the heart the pulse is often feeble, and indeed almost imperceptible, although the contractions of the heart, and especially those of the left ventricle, are much more energetic than usual. In apoplexy, on the contrary, the pulse is frequently strong, when the impulse or contraction of the heart is very feeble; facts which, according to Laennec, seem to be inexplicable, except, by supposing that the arteries act independently of the heart.

7. Further: cases have occurred, though very rarely, in which the pulsations of the arteries did not correspond with the systole of the heart. The instances referred to by Burns are of this description. According to Rudolphi, Zimmerman saw a woman, in whose right arm the artery generally beat only fifty-five strokes, while that of the left beat ninety or ninety-two. Dr. Elisha Bartlett has briefly reported a case of the same kind in the American Journal of Medical Sciences, May, 1836. The patient was a young female affected with chlorosis. She was subject to a strong and painful pulsation in the temporal arteries, which was not synchronous with the action of the heart. The average number of pulsations at the wrist was found by repeated counting to be one hundred and six; that of the pulsations of the temporal artery was eighty. A venerable medical friend mentioned to the author a similar case, which he had witnessed himself. On this subject Martini makes the following remark: "Ad hoc arteriarum micatus sæpenumero frequentiores deprehenduntur, quin cordis motus nihilum quidem increverint." The

same author further states the following fact: "Corde osseam firmitatem adepto, pergit sanguis per arterias promoveri."

8. There are some animals, in which a circulation exists, although they are destitute of a heart. And in fishes, which have only a venous or pulmonary heart, the arterialized blood is moved solely by vessels. The aorta is formed by the union of branches proceeding from the gills. To these facts may be added, a curious discovery made by Hall, of an artery in the frog and toad, which pulsates distinctly after the removal of the heart.

9. After the removal of the heart from a living animal, the blood may still be seen to flow in the small vessels. Mayo states, that in an experiment of Hall, a ligature was tied round all the vessels passing to and from the heart of a frog; yet the blood continued to flow with some rapidity into the arteries of the web of the foot; but after a few seconds it became slower, then stopped, when a retrograde rush of blood took place. After this, its ordinary flow was resumed, then a reflux again took place, and so on alternately, for a considerable time. Imperfect human fœtuses are sometimes destitute of a heart. In these the circulation must be carried on wholly by the action of the arteries and veins.

An important fact connected with this subject, which is mentioned by an old anatomist, I shall make no apology for citing in his own language: "Quanta arteriarum in protrudendo sanguine sit potentia, manifestè ab injectâ ligaturâ patet; vix enim eâ in vivente arteria etiam magna constringitur, quin statim ultrà vinculum, tempore quo vix tres quatuorve pulsationes peragerentur, omnino inanitur quamvis a corde, impediente fasciâ, nullum procedentem sentiat impulsum."*

It may not be amiss to mention, in this place, a curious fact, which has sometimes been observed, in cases of amputation of the lower extremities, viz. that scarcely any blood has escaped from the incision of the soft parts; and, upon examination, it has been discovered that the main artery of the limb was ossified, or converted into a rigid tube of bone. If it were certain, in these cases, that the ossified artery was pervious throughout its whole extent, the fact would form a curious counterpart to that cited above from Martini, viz. that in ossification of the heart, the blood still continues to circulate in the arteries. The true explanation of the phenomenon, however, we have probably yet to learn.

10. There is still another remarkable class of cases, in some respects analogous to those just mentioned, and still more irreconcilable with the doctrine of Harvey and Haller, that the heart is the sole moving power of the circulation. In these cases there

* De Back, Dissertatio de Corde.

is a cessation of pulsation in some of the large arteries in the upper or lower extremities, no *appreciable* disease existing in the arterial coats, and the action of the heart being perfectly natural. A remarkable case of this kind is reported in the Medical Chirurgical Review, for April, 1836. The patient was a young female aged 22, who had suffered a severe attack of pneumonia, from the effects of which she had not fully recovered. Three years afterwards, she was affected with pains in the legs and arms, and epigastrium, chills and febrile heat, furred tongue, confined bowels; the pulse ninety, and small. A few days after the reporter first saw her, she had no pulse at either wrist, while the heart and carotid arteries were acting strongly. At a subsequent visit, a few days later, the pulsation was found to have ceased about an inch below each clavicle, while *pain was elicited by pressure along the course of the main arteries of the arm.* Some days after, a slight vibration was perceptible in the left radial artery, while all pulsation had disappeared from the dorsal arteries of the left foot. Shortly afterwards, no pulsation could be found in any artery of the extremities. Severe pains were felt at the same time in some of the limbs, especially the left leg, which exhibited signs of incipient mortification, and was, therefore, removed by amputation. On loosing the tourniquet, very little blood escaped from the large arteries, and this without jet; while the smaller arteries bled freely, and several of them required the ligature. Upon slitting up the large arteries of the amputated limb, no trace of disease could be found in them. But they appeared smaller than usual. A very remarkable circumstance in this case, was the return of the pulse in arteries in which it had wholly ceased. This occurred repeatedly in the left radial artery. Another circumstance worthy of attention, was the pain and tenderness along the course of the large arteries of the arm, a fact which appears to point to a morbid state of these vessels themselves, as the cause of the absence of pulsation, for the action of the heart continued unaltered. This curious case suggests many interesting reflections, which it must be left to the reader to make. It will be found to be a problem of no easy solution, to reconcile it to the doctrine of Harvey and Haller. Cases of a similar kind are recorded by Parry and others.

11. To the facts and considerations above mentioned, may be added the experiments of Hastings, which appear to establish, beyond a doubt, the irritability of the arterial canals. In these experiments the larger arteries of different animals, the aorta, femoral, and carotid, were laid bare, and subjected to different irritations, of a mechanical and chemical nature; and the result, in general, was increased contraction of the vessel operated upon.

When the vessel was scraped with the scalpel, the irritation

produced a contraction in it, or rendered its pulsations more perceptible, or occasioned an irregularity in the surface of the artery, which appeared to rise from a permanent contraction of the fibres of the middle coat. In some instances, a contraction was produced, which remained after the death of the animal. The application of ammonia produced similar effects, notwithstanding the assertion of Bichat, that no contraction can be produced in arteries by means of alkalies. In one experiment, an artery was proved by measurement to have shrunk one-eighth in circumference by the application of ammonia. In other experiments, it increased the action of these vessels; for arteries which when first exposed scarcely pulsated, were very evidently contracted, and dilated immediately after being touched by the *liquor ammoniæ*. The nitric acid, also, occasioned a considerable contraction of the arteries.

12. The ganglionic nerves distributed upon the coats of the arteries and veins, probably confer upon these vessels some vital endowment. In other organs, as the heart, the intestines, and stomach, we find that this nervous influence is connected with a susceptibility to the influence of stimulants, and is, perhaps, the cause of it. One use of the nerves in the coats of the blood-vessels, perhaps, is to subject the blood to ganglionic innervation; another possibly may be, to render the vessels themselves excitable by the stimulus of the blood.

Mr. Swan remarks that the nerves have considerable power over the arteries independently of the heart, a fact which he says, "we have frequent opportunities of witnessing in diseases." In illustration of it, he mentions the case of a patient, who complained of numbness in the left side, attended with coldness and slightly diminished muscular action; the pulse on that side was weaker than on the right, where it was perfectly free and natural. The symptoms went off and returned several times within a few days, and had no connexion with organic disease.

According to Mr. S., the common opinion that the blood-vessels are furnished with nerves almost entirely by the great sympathetic, is a mistake. The aorta, it is true, is supplied by it, but many of the arteries receive contributions from the nearest branches of other nerves, by which means their actions, he remarks, become more readily associated with the actions of the parts to which they are distributed, and the supply of blood made to depend on the exigencies of the organs, and not merely on the action of the heart. The pain produced by tying up arteries, seems to show that they receive other nerves than those of the sympathetic.

When an arterial trunk, the direction of which is straight, is exposed in a living animal, in general no dilatation and no motion are perceptible to the eye during the systole of the left ven-

tricle. But on applying the finger to the vessel, the pulsation is readily perceived. According to Magendie, however, the dilatation of the aorta, during the systole of the heart, is manifest to the eye; and the same effect takes place in the divisions of the aorta of a certain magnitude; but the dilatation continually decreases in proportion as the arteries become smaller; and ceases wholly in those of a very small diameter. Mayo also asserts, that if an animal, in which the carotid artery is exposed, be excited or alarmed, as by holding its nostrils for a few seconds, the heart will contract with violence, and the artery, instead of lying pulseless and motionless, will leap from its place at every systole of the left ventricle, becoming elongated, and assuming a tortuous appearance.

In the arteries which are curved the pulsations are visible; because the impulse of the blood projected into them tends to straighten or extend them, which produces a sensible motion in the vessels. The curvature of the aorta is the place where this effect is most considerable.

Mayo states, that a partial dilatation of an artery may be produced, by exposing it in a living animal, and rubbing it for half a minute between the finger and thumb. A large artery in a living animal, as the carotid of an ass, or the crural artery of a dog, treated in this manner, becomes sensibly enlarged in the part subjected to the friction, assuming an ampullated appearance, which subsides in a quarter of an hour, if the wound be closed.

Functions of the Capillaries. The irritability of the capillary vessels has been demonstrated, in the most conclusive manner, by the experiments of Dr. W. Philip. In some of these experiments, the blood was observed to move in the capillary vessels, after the excision of the heart, and even after death. The web of a frog's foot was placed in the field of a microscope, and the capillary vessels were distinctly observed to contract on the application of stimuli. The capillary vessels of the mesentery were observed to move the blood some time after the death of the animal. Dr. Philip also found, that the motion of the blood in the capillaries is influenced by the application of stimulants to certain parts of the nervous system, in the same manner as the motions of the heart, and wholly independently of any control exerted upon them by this organ.

There are reasons for believing that the force of the heart and of the arteries is nearly exhausted when the blood reaches the capillaries. The motion of the blood gradually becomes slower, and the vital fluid ceases to move by jerks. Besides, the capillary vessels are the seats of the vital operations of nutrition, calorification, secretion, and hematosis; and it seems difficult to conceive that these processes, which are extremely variable in their activity, should not directly influence the quantity and the motion

of the blood which supplies them with materials. In microscopic observations the blood has been observed to hesitate in its motion, to stop, as if uncertain what course to take, and even to move in a retrograde direction, with astonishing velocity and for a long time. If a part be irritated, the blood is seen to flow towards it suddenly in the capillary vessels, as if these exercised an attraction for it.

The portal circulation furnishes a strong argument in favour of the doctrine of the vital contractility of the capillaries. It is impossible to conceive that the power of the heart, can extend through two capillary systems, which the portal blood is obliged to traverse. The capillary vessels themselves must be the principal agents of this circulation.

It appears to be owing to the contractility of the capillaries surviving the other powers of the circulation, that the larger arteries in dead animals are found empty. In most cases the capillaries remain alive and active throughout the system, for a considerable time after respiration has ceased, working, as Dr. Arnott expresses it, like innumerable little pumps, drawing the blood out of the arteries, and forcing it into the veins.

The influence of the heart, however, is not annihilated in the capillary vessels, but extends through the capillary system into the veins. Magendie found, that when he compressed the femoral artery in an animal, the blood flowed out more slowly from the femoral vein; and as soon as the pressure was removed from the artery, again spirted out in a larger curve. When the action of the heart is feeble, the remote parts of the system are pale and cold. It appears, on the whole, that the blood moves in the capillaries under a threefold impulse, viz. the action of the heart, that of the arteries, and that of the capillaries themselves. This last is probably the chief cause.

But besides this impulse, to which the blood is subjected in the capillary vessels, and which impels it forwards in the course of the circulation, and causes it to pass from the arteries into the veins, it is subject to another, which attracts it into the parenchyma of the organs, to be employed in nutrition, secretion, &c. Between these two impulses, the blood sometimes appears to hesitate, as if it were at a loss which to obey. The action of the heart moves it in the first direction; the peculiar action of the *nutrient* and *secretory* capillaries themselves draws it in the other. Any irritation applied to these vessels, increases the flow of blood towards them; a principle which is illustrated in inflammation. Hence, the attractive influence of the capillary vessels, regulates the quantity of blood which traverses the other parts of the circle of the circulation. They may either attract more or less blood to themselves, or refuse to receive it, and thus materially influence the course of blood in the great vessels,

change the pulse, and determine the quantity of blood which passes into the veins, and, consequently, of that which moves in the heart and arteries. The arteries and veins become larger in an organ which is the seat of a chronic irritation. From these, and many other similar facts, it appears not improbable, that the principal office of the heart is to propel the blood into the great arteries, which is thence drawn out, as it were, by the attractive power of the capillary vessels, determined by the wants of those parts of the system to which they belong.

When a part of the capillary system attracts to it more blood than usual, the fluxion extends to the neighbouring vessels, and from them gradually to the larger arterial trunks. Hence the increased action of the arteries which go to an inflamed part.

Each organ attracts from the great vessels different quantities of blood, according to its degree of vitality, and the activity of its functions. Even in the same part, the capillary circulation varies in its activity, according to the degree of excitement which happens to prevail. Every morbid condition of an organ is accompanied with a change in its capillary circulation. Further, there are some organs, whose functions are intermittent, as the uterus; and these must attract more blood into their vessels, when in a state of activity, than when at rest. All these considerations go to establish the importance of the functions of the capillary vessels, and appear to justify the opinion of Broussais, who considers the great vessels as a reservoir, to furnish the capillary system with blood; from which these last named vessels draw out only the quantity which they require.

The motion of the blood in the minute and capillary vessels is subject to various modifying influences.

A slight obstacle to the circulation, as the pressure of a ligature applied very gently to the limb; a very slight tension of the membrane submitted to the microscope, even a very trifling degree of dryness of the web, will produce a pulsatory motion, consisting of a more and less rapid flow alternately, or of alternate motion and rest of the blood in these small vessels.

When the powers of the circulation fail or become very feeble, the blood in these vessels becomes affected with a movement of oscillation, in which, during its systole, the heart appears to propel the blood into the extreme vessels, but during its diastole, the contractile and elastic power of the coats of the vessels, and the pressure of the contiguous parts, force the blood back in the opposite direction, the two powers thus impressing upon the vital fluid an alternate progressive and retrograde movement. This oscillatory motion becomes very striking if the action of the heart be entirely intercepted, either by the excision of the organ, or by a ligature round the aorta. In this case, says Hall, the globules flow along the minute arteries in an uninterrupted stream for several seconds, in consequence, as he supposes, of the contrac-

tion of its successive portions. It then suddenly reverses its motion and flows in the opposite direction, an effect which he ascribes to the diastole of the vessel.

It is difficult to determine the relative proportions of moving power which the heart, arteries, and capillary vessels respectively contribute to the circulation. In general, the further we advance from the heart the irritability of the arteries appears to increase; and in the capillary vessels it is so great as to be sufficient to give motion to the blood, in some measure independently of the heart. The irritability of the arteries, then, is most inconsiderable nearest the heart, where, of course, it is least needed; but in the capillary vessels, where the action of the heart is but little felt, this deficiency is compensated by a high degree of irritability of the vessels.

Functions of the Veins. The causes of the motion of the blood in the veins, also, have been a subject of much controversy among physiologists. These vessels possess little or no elasticity; for, though very dilatable, they appear to have little power of reaction upon their contents. They also appear to be endued with little, if any, irritability; and hence they seem to be incapable of contributing any contractile power, either physical or vital, to the circulation. It has therefore been supposed that the *vis a tergo*, derived from the heart, arteries, and capillaries, continues to operate in propelling the blood in the veins, while these vessels are regarded as mere passive tubes. This opinion, however, is liable to strong objections.

The quantity of blood contained in the veins appears to be too great to be sustained in the ascending branches, and kept in motion by the contractions of the heart and arteries, and the vital action of the capillaries, alone.

The veins are supposed to contain at least twice as much blood as the arteries; and a circumstance which, from the laws of hydrostatics, appears to be calculated to increase the pressure of this column of blood in the ascending veins is, that the fluid is constantly passing into a narrower channel in its ascent towards the heart. The contracting sides of the cone along which the blood moves, oppose a resistance to the motion of the fluid, which a considerable part of the moving force is expended in overcoming. So that the *vis a tergo* has not only to sustain and propel twice the column of blood contained in the arteries, but also to overcome a degree of resistance arising from the structure of the venous tubes, the amount of which it is difficult to estimate.

But setting aside this difficulty, and supposing that the *vis a tergo* were sufficient to propel the blood in the ascending veins, it is evident that these vessels would always be in a state of great distention. In the lower extremities especially, they would have to sustain such a degree of lateral pressure as would keep their coats constantly on the stretch. Yet we do not find that this is

the actual condition of the veins of the feet and legs. They never become so much distended as to be converted into rigid tubes; which, however, would necessarily be the case with these vessels if the blood moving in them were propelled solely by a force from behind. For so long as the veins yielded to the pressure of the blood, this fluid, instead of rising in these vessels, would be accumulating in and distending them; and not until their sides were distended to the utmost, would the propulsive power behind be enabled to force the blood upwards.

Another force, which has been considered as one of the moving powers of the venous blood, is the contraction of muscles in contact with the veins, or through which these vessels pass. This has been inferred from the quickened circulation, and the strong pulsations of the heart and arteries, which follow great muscular exertions. The muscles during their contraction swell and press upon the veins in contact with them, and force the blood from the parts immediately subjected to their pressure. The blood, then, has a tendency to move in all directions from the centre of pressure, but is prevented from flowing in a retrograde direction, by the valves with which the vessels are provided; and, of course, is necessarily directed towards the heart. When the muscle is relaxed, the vein is relieved from the pressure, and receives a new supply of blood from the capillaries. It is evident, however, that muscular contraction must be a secondary, and by no means a principal agent; for there are certain diseases, as fever, in which the muscles are perfectly at rest, and yet the circulation, and of course the motion of the venous blood, is as impetuous as after violent exercise. And besides, it appears extremely improbable that nature would have relied for the continuance of a function which cannot be suspended for a moment without destruction, upon an agent so precarious and uncertain as the action of the voluntary muscles.*

Muscular action seems to be most necessary to promote the flow of the venous blood in those parts of the system where the veins are destitute of valves, as in the abdomen. Hence a congestion of venous blood in the portal system, engorgement of the liver, and enlargements of the hemorrhoidal vessels, are the natural consequences of inactive and sedentary habits of life.

The veins themselves also exert a motive action upon the blood. This action is different from that of the heart, but is not simple elasticity; for if a vein be punctured between two ligatures, the blood spirts out with greater force during life than after death. Indeed, it is said that true irritability exists in the great venous trunks, as the vena cava inferior, especially in cold-blooded animals. Every one has noticed the shrinking of the external veins,

* Carson.

as of those in the back of the hand, in cold weather. They contract perhaps to one-third of their ordinary diameter.

A singular fact mentioned by Hall, which seems to favour the opinion of the contractile power of the veins, deserves to be noticed in this place. He states that when the course of the blood along a large vein is arrested, the "vessel immediately assumes the character of an artery, apparently giving off branches instead of receiving roots; the globules of the blood pursuing a retrograde course."

Further: Hastings found that both the capillary veins and the large venous trunks, readily and sometimes violently contracted on the application of certain stimuli. The oil of turpentine applied to small veins, occasioned a great contraction of their diameters. The nitric acid produced so strong a contraction in veins irritated by it, that the passage of the blood was almost wholly prevented. On applying nitric acid to a trunk of one of the pulmonary veins in the thorax of a cat, the vessel with all its branches became much contracted. A similar effect was produced in the abdominal cava of a cat, by the application of nitrous acid. When the experiment was performed after death, the vessels became white from the contact of the acid, but suffered no contraction of their coats. These facts demonstrate a vital power of contraction in the veins, from which it may be inferred, that they are not mere passive tubes in the function of the circulation. In some situations, however, the veins cannot contract upon the blood, from their connexions with the neighbouring parts. This is the case with the veins of the liver, and those which pass through the substance of bones. The sinuses of the dura mater are in the same predicament.

Another force, which has been supposed to assist in giving motion to the venous blood, is an aspiratory power existing near the source of the circulation, which draws or sucks the blood into the heart. That such a power exists it seems impossible to deny. What else is it which empties the veins into the heart, when a ligature which intercepts the *vis a tergo*, is applied to them? An experiment described by Harvey sets this fact in a strong light. "Sed in serpentibus et piscibus quibusdam, ligando venas per aliquod spatium infra cor, videbis spatium inter ligaturam et cor valdè cito inaniri." This aspiratory power consists of two forces, viz. the active dilatation of the heart, and the expansion of the thorax in inspiration. On opening the thorax of a living animal, and applying the finger to the heart, it will be perceived that the dilatation of the organ is an active operation, and not a mere relaxation of its muscular fibres. So, where the heart of a frog is cut out and put into warm water, it will continue to contract and dilate with great energy, throwing jets of the fluid to some distance. Œsterreicher witnessed a fact show-

ing the great power with which the heart dilates. He saw the heart of a young dog which weighed scarcely half a pound, throw up a weight of six and a half pounds to some height (in der höhe); and Magendie says that when the ventricles dilate it is with very great force, a force which, in animals recently dead, he had many times observed to be capable of raising a weight of twenty pounds. Another fact which is favourable to the same opinion is, that after death, the ventricles are generally found distended with blood, from which it seems to follow that the state of dilatation is the natural condition of the organ.

Dr. Bostock regards the dilatation of the heart as the effect of the elasticity of the organ, overcome at first by its irritability, which from the contact of the blood causes it to contract to a smaller volume than that at which its elasticity would maintain it; but after the stimulating cause is removed by the contraction of the ventricle, the elasticity being no longer counteracted is left at liberty to exert itself, and restores the heart to its former volume.

The suction power of the heart, however, is not admitted by all physiologists. Dr. Arnott denies it and asserts that, even admitting it to exist, it could not promote the motion of the blood in the veins, because these vessels being pliant flexible tubes, would collapse by the atmospheric pressure, instead of suffering the blood to be pumped up in them, by the suction of the heart. If the point of a syringe be inserted into a piece of intestine or eel skin, or a vein filled with water, on attempting to pump up the water, by drawing the piston of the syringe, the water nearest the mouth of the syringe, Arnott observes, will be drawn in, and then the sides of the tube will collapse, acting as a valve to the mouth of the instrument, and putting a stop to the experiment. This experiment of Arnott's, however, is not a fair representation of the actual condition of the veins in the living body. For while the circulation is going on, the capillary vessels are constantly forcing blood *into* the veins, as fast as it is flowing *out* of them by other causes. The experiment, in order to be satisfactory, ought to be performed in a different manner. Into a piece of intestine, or eel skin, filled with water, should be inserted not only one syringe to draw the water *out*, but another at the opposite extremity to force it *in*, in the same proportion, so as to keep the vessel constantly full. Then the atmospheric pressure could not make the tube collapse, but would be exerted upon the column of fluid contained in it, and force it into the upper syringe.

But even if the principle of Arnott's reasoning be admitted, there is a circumstance in the structure and attachments of many of the larger veins which makes it inapplicable to them. It seems that some of the veins are prevented from collapsing either by

their attachment to the neighbouring parts, or by some peculiarity of mechanism. This has long been known to be the case with the sinuses of the brain, and the hepatic veins. But according to M. Berard, there are certain peculiarities in the structure of some of the other veins, by which the same object is accomplished. Thus the mouth of the superior vena cava is kept patulous, and in a state of constant tension, by the process of the pericardium which extends over it; and the subclavian veins, and the junction of the jugulars with them, as also the axillary veins along their whole course, from the scaleni muscles to the arm-pit, are maintained in a similar state by their attachment to various aponeurotic membranes, at the bottom of the neck. These veins, therefore, when divided *do not collapse,* unless separated from the parts which keep them on the stretch. The inferior cava may be considered as placed in similar circumstances by its connexion with the diaphragm, through which it passes. Accordingly, it always remains extended, *and never collapses,* even when empty. Hence, according to M. Berard, as the principal veins are thus prevented from collapsing, and are enabled to resist the pressure of the atmosphere, the suction power of inspiration is exerted with effect in pumping the blood from the veins into the heart, and in promoting the motion of the venous blood through the liver.

The absence of a similar structure in the great veins leading to the extremities, it is supposed must render this power wholly useless in the venous circulation of the other branches of the inferior cava, and this might be admitted were not these vessels kept from collapsing by the blood constantly passing into them through the *vis a tergo.*

It is owing to this structure that air is sucked into a large venous trunk at the bottom of the neck, when wounded in surgical operations.

The expansion of the thorax during inspiration, is another force, which promotes the flow of venous blood towards the heart. Inspiration establishes a kind of focus of suction in the chest, by which both air and blood are drawn into it. When the chest is dilated by inspiration, the jugular veins are observed to empty themselves and collapse; but during expiration they rise, and become turgid with blood. Magendie introduced a gum elastic tube into the jugular vein of a living animal, so as to penetrate into the vena cava, and even into the right auricle, and the blood was observed to flow from the open extremity of the tube only at the time of expiration. During inspiration, the suction power drew the blood into the chest, and prevented its rising in the tube. Barry inserted one end of a spiral tube into the jugular vein, and plunged the other into a vessel filled with coloured fluid. During inspiration, the fluid was drawn from the

vessel *into* the vein, but, at the time of expiration, it remained stationary in the tube, or was repelled into the vessel.

On the whole, the effect of inspiration is to promote the flow of blood towards the chest, and, of course, to empty the remote parts of the circulating system; while expiration produces the opposite effect, obstructing the flow of blood to the chest, and engorging the periphery of the circulation. During expiration the blood moves with greater force in the arteries than during inspiration.

It appears from experiments that the influence of respiration on the motion of the venous blood is greatest near the heart, and gradually diminishes as the distance from that organ increases.

It must be considered, however, in reference to the influence of the expansion of the chest upon the circulation, that there is only one act of respiration, for every five or six pulsations of the heart; and, consequently, that the blood passes five or six times into the auricles of the heart, while respiration takes place but once. In the fœtal state, respiration does not exist, yet the circulation has a much greater velocity than after birth.

It appears, on the whole, that a variety of causes concur, in giving motion to the venous blood, viz. the *vis a tergo* derived from the action of the heart, the arteries, and the capillary vessels; the contractile power of the veins themselves; the aspiratory action of the heart; the expansion of the lungs in inspiration; and the contraction of the muscles in contact with the veins.

Some of the German physiologists assume a self-moving power in the blood, by virtue of which it exerts an effort to diffuse itself throughout the body. They assert, that the blood seeks out or makes new passages for itself in the organs. So in the incubated egg, globules of blood, it is said, may be seen moving in currents, before the vessels are formed.

Influence of the Nervous System upon the Heart.

The heart is more independent of the great nervous centres, particularly of the brain, than many other organs. If the thorax of a cold-blooded animal be opened, and the nerves which are distributed to the heart be subjected to any kind of irritation, the action of this organ is neither accelerated, nor sensibly affected in any mode. Acephalous fœtuses frequently live until birth, and sometimes a few days longer. Reptiles have lived six months without a head; and mammiferous animals may live some time after the loss of the head, if the vessels of the neck be tied to prevent death by hemorrhage, and respiration be maintained artificially.

The principle of the heart's action appears to reside in the organ itself, though some physiologists suppose it to be derived

from the nerves distributed throughout its substance, derived from the ganglionic system and the *par vagum;* and the innervation of the cerebro-spinal axis, particularly of the dorsal part, is supposed to be necessary to the motions of the heart, in their perfect developement.

The influence of the nervous system upon the circulation is established by many facts. After a considerable injury to any part of this system, as the spinal cord, the brain, or the nerves themselves, the circulation of the blood is enfeebled or partially destroyed, in the part whose nerves have been isolated from the rest of the nervous system. For example; if the sciatic nerve be divided, the circulation, it is said, becomes feebler by degrees, and at length wholly ceases in the lower extremity of the same side; but remains unimpaired, or nearly so, in the other parts of the body. The heart's action is impaired by the division of the principal nerves proceeding from the spinal marrow, and the more so as more of these nerves are divided. Very severe injuries of the brain, or spinal cord, sometimes occasion a total cessation of the circulation. The influence of the nervous system upon the living blood itself, transmitted by the coats of the blood-vessels, is supposed by some physiologists to be sufficient to maintain the circulation of the blood in particular parts, without the aid of the heart.

A celebrated doctrine on this subject was that of Legallois, who attempted to demonstrate that the heart derives its principle of action from the spinal marrow. It appears, however, from the experiments of Philip, Clift, and Brachet, that the action of the heart survives the destruction of the spinal cord, especially in young animals, and if the operation be performed slowly. The absence of this part of the nervous system, it appears further, does not prevent the action of the heart in fœtuses destitute of it.

But it should seem from facts mentioned by Brachet, that the great sympathetic exerts the greatest nervous influence over the heart. This writer cites from Hufeland's journal, some experiments of Bartels on persons who had been beheaded. Six highway robbers had lost their heads near Marbourg, and on opening the bodies of the whole six, a few minutes after their execution, the heart was observed to contract and dilate alternately, with considerable force, and in a regular manner. The motions, however, gradually diminished in strength, for the space of half an hour, but were instantly re-excited, by irritating a filament of the great sympathetic; while the irritation of the spinal marrow, merely gave rise to contractions of the muscles of the trunk, without producing any effect whatever upon the heart.

The influence of the sympathetic upon the action of the heart was demonstrated in a very conclusive manner by experiments on dogs, performed by Brachet himself. In these experiments

Brachet succeeded, after many failures, in isolating, on each side, the inferior cervical ganglions, and, upon dividing all the filaments which proceeded from them, he found that the action of the heart, after a few irregular contractions, was almost immediately annihilated, and the circulation ceased.

In another experiment, he exposed the cardiac nerves, and followed them into the chest until he reached the cardiac plexus. Having succeeded in isolating this body, he divided it with a pair of scissors; upon which the circulation instantly stopped, the heart ceased to contract, and the animal became rigid, and expired. From these experiments, Brachet inferred, that the heart derives its principle of motion from the ganglionic system. Bouillaud inclines to the same opinion.

Some very curious experiments of Weinhold deserve to be mentioned in this place, though doubts may exist as to some of the inferences to be legitimately drawn from them. He beheaded a cat, and after the complete cessation of the pulsation of the arteries, and of muscular action, he removed the spinal marrow, and substituted in its place an amalgam of mercury, zinc, and silver. The pulsations of the arteries immediately recommenced, and muscular action was renewed, the animal executing several leaps. After the irritability seemed to be exhausted, Weinhold established a communication between the heart and voluntary muscles, and the amalgam in the spinal canal, by means of a metallic arc, and succeeded in again reviving general though feeble contractions.

In another experiment, he filled with the same amalgam the cranial and vertebral canal of a cat, which exhibited no sign of life; when the animal raised its head, opened its eyes, looked steadily, attempted to walk, and even to raise itself, after repeatedly falling down. The circulation and arterial pulsations were very active during all this time, and continued for a quarter of an hour after the chest and abdomen were opened. In a dog, whose cranium only was filled with the amalgam, he observed that the pupil contracted on the approach of light; and when a lighted candle was placed near it, the dog manifested a desire to avoid it. The animal also listened when a person made a noise by striking with a key upon a table.

These experiments are infinitely curious and remarkable, but it is hardly possible to read the account of them, without feeling a shade of doubt pass over the mind, whether they are to be considered so much experiments upon brainless cats and dogs, as upon certain brainless animals of a higher order.

The heart is wholly exempt from the jurisdiction of the will, though powerfully influenced by the passions or mental emotions. There is one remarkable case on record, however, that of a Captain Townsend, who could stop the action of the heart, and re-

store it again at will. The story is so marvellous as very naturally to have excited some distrust among physiologists; yet a few years since I knew a young man, who possessed in a slight degree a similar power. He could accelerate or retard the motions of his heart by a mental effort. If the pulse were sixty in a minute, he could raise it to eighty, or lessen it to forty. The effort was purely a mental one, and was not accompanied by any muscular action. The change of the pulse took place immediately; but on the cessation of the effort, the pulse did *not* return immediately to its previous state. The effort produced a feeling of weakness, and he made it reluctantly. In this case organic lesion of the heart was suspected to exist.

CHAPTER XV.

RESPIRATION.

The third and last of the vital functions, is respiration, a function which is indispensable to animal, and even vegetable existence. By respiration, the assimilation of aliments, which commenced in the stomach and intestines, is finally completed in the lungs, by their conversion into blood; and this fluid itself, after being drained of its nutritive and vivifying principles, in administering to the various operations of life, is again reanimated by the influence of atmospheric air, and prepared anew to dispense life and nutrition throughout the system.

In the human species, and the higher classes of animals, respiration is accomplished by certain organs, called the lungs; two viscera, which fill the cavity of the thorax, of a spongy texture, extremely vascular, and divided into lobes. The two lungs are separated from each other, by the *mediastinum* and the heart, and are enveloped by membranes, termed the *pleuræ*. Their figure corresponds with that of the cavity of the thorax, with the walls of which they are always in contact, so that no air can intervene between them. In consequence of their tissue, after birth, being always penetrated with a great quantity of air, their specific gravity is less than that of water, and they swim when placed in this fluid.

The substance of the lungs is composed of innumerable fine cells, connected together by a delicate cellular membrane. Each lung is divided by deep fissures into sections, termed lobes, of which the right lung contains three, the left only two. Each of these lobes is subdivided into smaller lobes, or lobules, and these,

again, into the fine cells above mentioned. Each lobule is surrounded by a thin layer of cellular tissue, which separates it from the adjoining lobules. Each lung is attached to the spine by its root, where blood-vessels, nerves, lymphatics, and a branch of the windpipe enter it. The lungs are covered by a transparent membrane, termed the pleura, which is reflected from the root of the lungs, over the spine and sternum, ribs, intercostal muscles, and diaphragm.

Air is admitted into the lungs, by means of the trachea or windpipe, a tube eight or ten inches long, composed of cartilaginous arches, or imperfect rings, deficient on the posterior side; of cellular and muscular coats, and a lining of mucous membrane.* The canal is completed behind by a fibrous membrane. The trachea is situated before the vertebral column, in the posterior mediastinum, resting on the œsophagus, and extending from the lower parts of the larynx to the level of the second or third dorsal vertebra. Here it bifurcates, or divides into two branches, termed *bronchia,* one of which passes to the right lung, and the other to the left.

Each of the bronchia subdivides, as it enters the lung; the right into three branches, which are severally distributed to the three lobes of the right lung; the left into two, corresponding with the two lobes of the left lung. As they penetrate into the lungs, they subdivide more and more, branching throughout the whole pulmonary tissue, until their extreme divisions terminate in the fine vesicles which constitute the principal part of the substance of the lungs. Each ramification of the bronchia is connected with a particular cluster of these cells, and if air be forced gently into it, it will inflate this, but none of the neighbouring cells, unless the force employed be so great as to rupture the sides of the cells. The air cells are said to be about the one-hundredth of an inch in diameter.

The trachea and bronchia are lined by a mucous membrane, which is a continuation of the membrane of the larynx, and extends to the termination of the bronchia. It is lubricated with mucus, secreted by mucous follicles interspersed throughout it. The outer membrane of the tracheo-bronchial tube consists of longitudinal and parallel fibres, and is considered by some as analogous to the muscular tunic of the intestines, but by Beclard, as identical with the yellow tissue of the arteries. This membrane connects together the cartilages of the trachea posteriorly, filling up the deficiency of the cartilaginous rings, and completing the formation of the tracheal tube.

* It is a curious fact, that birds can live several hours with the trachea tied, provided one of the hollow bones, into which the air penetrates in respiration, be sawed open so as to admit the air. But if a vessel containing carbonic acid, or azote, be adapted to such an opening, the bird soon dies.

In the smaller divisions of the bronchia, the cartilaginous arches wholly disappear, and the fine aerial canals consist merely of the fibrous and the mucous membranes.

The lungs are supplied with two distinct circulations, one of which is destined to the nutrition of the organs, the other is connected with their peculiar functions, viz. respiration, or hematosis. They receive first, arteries which spring from the aorta, and convey arterial blood for the nutrition of the lungs, ramifying over the bronchia, and termed the *bronchial* arteries; and secondly, the *pulmonary* artery, a large vessel which arises from the right ventricle of the heart, and conveys venous blood to the pulmonary capillary system, in order to be converted into arterial blood by respiration.

These organs also possess two capillary systems; viz. one, which is a part of the *general* capillary system, is the seat of the nutrition of the lungs, and of the transformation of arterial into venous blood, and intermediate between the bronchial arteries and veins; the other, or the *pulmonary* capillary system, is the seat of the peculiar functions of the lungs, or of the conversion of venous into arterial blood. This is intermediate, between the pulmonary artery and the pulmonary veins.

The extreme branches of the bronchial arteries anastomose freely with one another, and also with the minute ramifications of the pulmonary artery and vein.

The bronchial veins open for the most part into the pulmonary veins.

The lungs are abundantly supplied with lymphatics and conglobate glands. The latter are situated at the bifurcation of the trachea, around the bronchia, and some of them are found in the interior of the lungs. The nerves of these organs are derived from the pulmonary plexus, formed by branches of the pneumogastric, and the great sympathetic.

The thorax, or chest, in which the lungs are situated, is a box of bones, formed anteriorly by the sternum, laterally by the ribs, of which there are twelve on each side; and posteriorly by the dorsal vertebræ. The seven superior ribs are termed true ribs, the five lower ones, false. The true ribs are attached posteriorly to the vertebræ, by movable articulations, and anteriorly with the sternum, by cartilaginous prolongations. The ribs are connected together by two strata of muscles, which are termed intercostal. Below, the thorax is bounded by the midriff, or diaphragm, which separates it from the cavity of the abdomen. This muscular partition, though dividing the trunk of the body transversely, does not form a horizontal plane, but arches upwards into the thorax, forming a considerable concavity, when viewed from the abdomen.

All the parts of the thorax are movable, and are so arranged,

that its cavity may be enlarged in every direction. It may be enlarged vertically, by the contraction of the diaphragm; for in contracting this muscle loses in some measure its arched form, and becomes depressed and flattened towards the abdomen, so as to diminish this cavity, and enlarge, in the same measure, that of the thorax. Laterally, the thorax may be enlarged by the elevation and abduction of the ribs, the arches of which are drawn upwards and outwards, by the contraction of the intercostal muscles; and, in the antero-posterior direction, its cavity may be increased, by the elevation of the sternum.

There are several muscles employed in giving motion to the walls of the thorax. These are, besides the diaphragm and intercostal muscles, the *serrati*, the *scaleni*, the *subclavius*, the *levatores costarum*, the pectoral muscles, the abdominal muscles, &c.

The phenomena of respiration may be divided into three classes, *mechanical*, *chemical*, and *vital*. The *mechanical* phenomena comprehend the mechanism by which air is alternately drawn into and forced out of the lungs; the *chemical* relate to the changes which the air undergoes in the lungs; and the *vital*, to those which are effected in the blood by the contact of the air.

Mechanical part of Respiration.

The mechanism of respiration may be reduced to the two phenomena of *inspiration* and *expiration*, or the alternate introduction of air into the lungs, and its expulsion from these organs.

Inspiration, or the introduction of air into the lungs, is effected by the dilatation of the thorax, which is accomplished by the depression of the diaphragm, and the elevation and abduction of the ribs and sternum. By these motions, the cavity of the chest is enlarged in its three principal diameters, vertical, lateral, and antero-posterior. The vertical diameter, extending from the centre of the diaphragm to the top of the chest, is seven or eight inches in length, and this is increased by the contraction of the diaphragm, from two to four inches, according to the depth of the inspiration. It is chiefly the lateral parts of this muscle, which become depressed in inspiration, its centre being tendinous and incapable of contraction, and besides, being fixed by its attachment to the sternum and to the pericardium. According to Lenhossek, the increase of the capacity of the thorax, caused by the contraction of the diaphragm, is five times greater than that which is produced by the action of the other muscles of inspiration.

The lateral, or transverse diameter, is nine or ten inches in length, and is increased by the ascent of the ribs to eleven or twelve. The arches of the ribs are drawn outwards as well as upwards, during their elevation; an effect which is owing to the

obliquity of the planes which pass through their arches, in relation to the spinal column, with which they are articulated. From the same cause, the sternal extremities of the ribs advance forwards in their ascent, carrying the sternum with them, and thus increasing the depth of the chest from before, backwards. This diameter is five or six inches in length, and may be increased by the elevation of the ribs, from an inch to an inch and a half. The increase of the transverse diameter of the chest is the greatest about the seventh and eighth ribs, where the horizontal diameter is the largest. In females a greater range of motion is bestowed on the ribs, on account of the impediment to the free descent of the diaphragm, occasioned by the gravid uterus in pregnancy.

The elevation of the ribs is accomplished, in ordinary inspiration, by the contraction of the intercostal muscles. The first rib is made a fixed point, by the action of the scaleni and subclavian muscles, and all the others are raised towards the first, by a general and simultaneous movement, caused by the action of the intercostal muscles.

In difficult or excited respiration, several other muscles contribute their aid, in elevating the ribs; as the *great serrati*, the *superior serrati postici*, the *pectoral* muscles, the *latissimus dorsi*, the *sterno-cleido-mastoid*, &c.

According to Magendie, there are well marked degrees of inspiration, viz. 1. *Ordinary* inspiration, which is effected by the depression of the diaphragm, and a very gentle and scarcely perceptible elevation of the thorax. 2. *Full* inspiration, in which there is a very evident elevation of the thorax, as well as depression of the diaphragm. 3. *Forced* inspiration, in which the dimensions of the chest are enlarged to the utmost, in every direction. In the first, or ordinary degree of inspiration, the air penetrates only a part of the pulmonary tissue; in the second, it inflates a larger portion of the lungs; but it is only in the third, that the whole extent of these organs is pervaded by it. In the third degree of inspiration, several muscles are employed, which are attached by one of their extremities to the arms; in consequence of which, it becomes necessary that the arms be previously fixed, or made a point of support for these muscles to act upon. Hence, in violent dyspnœa, from asthma, or any other cause, the sufferer instinctively seizes the arms of his chair, or any other solid body, in his efforts to elevate the ribs and expand the thorax. In making violent efforts, on the contrary, as in raising heavy burdens, pushing, &c. in evacuating the bladder, or the rectum, and in the efforts of parturition, *the walls of the thorax* are made a fixed point for the muscles of the arms or abdomen, by taking a deep inspiration, and then closing the glottis, to prevent the escape of the air from the lungs. If the muscles which close the glottis be paralysed, by dividing the laryngeal

nerve, or the glottis be kept open by the introduction of a canula, a strong effort becomes impracticable.

The condition of the lungs in the thorax has been compared to that of a bladder enclosed in a receptacle having movable walls, in such a manner that no air can penetrate between the two, and that the mouth of the bladder opens to the external air. In these circumstances, if the walls of the receptacle be separated farther from each, the effect will be to remove the pressure of the atmosphere from the external surface of the bladder, while its internal surface will remain exposed to it, by means of its mouth, which opens externally. The weight of the atmosphere thus acting upon the internal surface of the bladder, and not being counteracted by any external pressure, will keep this membranous sac in close apposition with the walls of the receptacle, and oblige it to follow all the motions of the latter.

The situation of the lungs enclosed in the thorax is very similar; and, consequently, when the chest is expanded by the action of the inspiratory muscles, all pressure is removed from the external surface of the lungs, the air contained in these organs expands by its elasticity, and keeps their external surface in close contact with the walls of the chest; and a volume of air, at the same time, rushes through the glottis and windpipe into the lungs, sufficient to restore the equilibrium between the rarefied air contained in these organs, and the external atmosphere.

The first act of inspiration, after birth, may be accounted for in the same manner. The inspiratory muscles of the new-born infant are excited to action, either by the irritation of the external air, or by an instinctive feeling then first developed; the chest is expanded, air rushes in through the windpipe and unfolds the lungs, and respiration commences.

Expiration, or the contraction of the thorax, which succeeds inspiration, is the result of several forces. These are of two kinds, *passive* and *active*. The passive are the weight of the ribs and parietes of the chest; the resilience, or elastic reaction of the sterno-costal cartilages which had been put on the stretch, and subjected to a degree of torsion in inspiration; and the elasticity of the bronchial tubes. The active powers are the abdominal muscles, which force the viscera against the diaphragm and thus diminish the vertical diameter of the chest. Another effect of the action of the abdominal muscles, is to fix the inferior ribs, so as to make them a point of support, towards which the superior may be drawn by the intercostal muscles, which may thus be rendered instruments of expiration. The *sacro-lumbalis*, the *longissimus dorsi*, the *serrati postici inferiores*, the *quadratus lumborum*, the *triangularis sterni*, contribute to the same effect, that of depressing the inferior ribs, and diminishing the transverse and antero-posterior diameters of the thorax.

According to Magendie, expiration, like inspiration, presents three degrees, viz. 1. *ordinary;* 2. *large;* and, 3. *forced* expiration. In the first degree, or *ordinary* expiration, there is a diminution of the vertical diameter, produced by the relaxation and ascent of the diaphragm into the thorax; this muscle being pushed up by the abdominal viscera, which are compressed by the anterior muscles of the abdomen. The second degree, or *large* expiration, is the effect of the relaxation of the muscles which elevate the chest, permitting the ribs and sternum to sink down by their own weight, and to resume their ordinary relative situation, in respect to the vertebral column. *Forced* expiration is the result of a powerful contraction of the abdominal and the other expiratory muscles, pushing the diaphragm up into the chest, and producing the utmost possible depression of the ribs.

The oblique and transverse muscles of the abdomen, however, which are considered as the antagonists of the diaphragm and the principal agents of ordinary expiration, are not essential to this function, and perhaps have less concern in it than has been generally supposed. If the ribs were drawn down by the contraction of these muscles, we should expect that they would feel tense and rigid during expiration, which is not the fact. Besides, in extensive wounds of the abdomen, where the bowels are protruded, respiration could not be carried on, if expiration were effected by or required the pressure of the abdominal viscera against the diaphragm; for in these cases the intestines instead of being pressed up against the diaphragm are always protruded through the wound; and what is worthy of notice, this protrusion takes place *during inspiration;* a fact which proves that it is at this time that the intestines suffer the greatest pressure, and not during expiration, when they are supposed to be so strongly compressed by the action of the abdominal muscles. To these considerations, it may be added, that in certain experiments, these muscles have been divided transversely, or even altogether removed, and yet respiration has continued for a considerable time.*

Carson considers the elasticity of the lungs as an important agent in expiration. The lungs have a strong tendency to collapse, and they are prevented from obeying this tendency, only by the pressure of the air within them. But if an opening be made into the cavity of the chest, so as to expose the external surface of the lungs to the atmosphere, and thus equalize the pressure on their external and internal surfaces, then the lungs are left at liberty to exert their collapsing power and to assume the dimensions which their structure and their elasticity make natural to them. Hence, wounds penetrating into the thorax are followed by a collapse of the lungs and cessation of respiration

* Carson.

on the injured side of the chest. Carson found, by experiments on calves, sheep, and dogs, that the collapsing effort of the lungs was equal to the pressure of a column of water from a foot to a foot and a half in height. It should seem from this, that the lungs are in a forced state of expansion during life, and that they have a constant tendency to collapse, and to recede from the walls of the thorax. When the inspiratory muscles cease to act, and to maintain the chest in a state of dilatation, the collapsing power of the lungs may be exerted with effect, to a certain extent; because then there is nothing to prevent it. The lungs then shrink to their former volume, forcing out the air which had been admitted by the preceding act of inspiration; and, as the lungs shrink, the diaphragm and intercostals, now passive, offer no resistance to the external air which presses upon the walls of the thorax, keeping them in contact with the collapsing lungs, so as to prevent the formation of a vacuum in the chest.

According to Rudolphi, the larynx, trachea, and lungs themselves, take an active part in respiration. The larynx, he remarks, is in incessant motion in the act of breathing. In inspiration, the arytenoid cartilages are drawn apart by the muscles, which go to them from the thyroid and cricoid cartilages, and the glottis is thus opened. In expiration, on the contrary, the arytenoid cartilages are drawn towards each other again by their own proper muscles, and the glottis is thus closed. In birds, and the amphibia, which are destitute of an epiglottis, these motions, according to Rudolphi, may easily be seen by drawing the tongue forward, or bending back the lower jaw.

With the larynx, the trachea, with all its branches, or the lungs themselves, are in simultaneous action. While the arytenoid cartilages are separated from each other in inspiration, the inner or longitudinal fibres, which run the whole length of the trachea and its ramifications, contract, by which means all these parts are raised and dilated so as to offer an easy admission to the air. These fibres afterwards become relaxed, and the air passages are contracted—an effect to which the transverse muscles of the trachea contribute; and the air is thus expelled.

Treviranus asserts that an evident motion may be observed in the lungs of quadrupeds, after the removal of the intercostal muscles and diaphragm; and in reptiles, if the thorax be opened and the heart removed, the lungs may be observed alternately to contract and expand, and their motions may even be accelerated by stimulants. Another fact which affords a strong argument in favour of the irritability of the lungs is, that they are liable to spasmodic affections and to paralysis. The first condition appears in the form of nervous asthma, or dyspnœa; and sudden death sometimes appears to result from the second.*

* Lenhossek.

According to this view, all these parts are active in respiration, and of course the comparison of the lungs to a bladder, which is partially expanded and contracted by the ingress and egress of air, is wholly unsuitable. The fibres of the lungs, according to Rudolphi, can even act when these organs have grown to the side, and externally are wholly immovable.

These are some of the principal facts relating to the physical or mechanical part of respiration.

Chemical phenomena of Respiration.

The *chemical* phenomena relate to the changes which the air received into the lungs undergoes in respiration.

The atmosphere is that invisible elastic fluid which surrounds the earth to the height of about forty miles, and which is absolutely necessary to the existence of all organized living beings, vegetable as well as animal. Its specific gravity, compared to that of water, is as 1 to 770. A column of it, extending to the top of the atmosphere, is equal in weight to a column of water of the same diameter, thirty-two feet, or to a column of mercury twenty-eight inches in height. The pressure which it exerts upon the human body is consequently enormous, amounting to between thirty and forty thousand pounds on a middle-sized adult.

Atmospheric air is composed essentially of three elements, viz. oxygen, azote, and carbonic acid—in the proportion of 20 or 21 per cent. of oxygen, 78 or 79 of azote, and 1 or 2 of carbonic acid.

Oxygen is an invisible aeriform body, rather heavier than atmospheric air, possessing a strong tendency to combine with many other substances in nature, and forming with them certain compounds called acids and oxides; it enters into the composition of air, water, and of all vegetable and animal substances; is the principal supporter of combustion, and is an element essential to the formation and renovation of the blood, both in aerial and aquatic animals.

Azote is an invisible, gaseous body, lighter than oxygen and atmospheric air, and incapable of supporting combustion. In most animals, it is incapable of supporting respiration, though according to Vauquelin, it is the element which supports it in several of the inferior classes of animals. It is one of the essential elements of animal matter, and exists in some families of plants. Experiments seem to have proved, that it is both absorbed and exhaled in respiration.

Carbonic acid, also, is an invisible aeriform substance, of a slightly acid taste, of a greater specific gravity than azote or oxygen, capable of forming salts by combining with salifiable oxides, irrespirable by animals, and extinguishing burning bodies. Though it occasions asphyxia in animals who inhale it, it seems

to be essential to the respiration of plants. It is always present in atmospheric air, though in a very minute proportion.

Atmospheric air contains also, the imponderable elements, light, heat, and electricity; more or less of watery vapour; exhalations from plants and animals; and many other accidental admixtures.

The presence of the essential, as well as the accidental ingredients of the atmosphere, may be determined without difficulty. The presence of oxygen is ascertained by the combustion of a lighted taper in air; that of carbonic acid by its making lime-water turbid; and that of azote, by the formation of ammonia with hydrogen, in the conditions requisite to the combination of the two elements. Caloric and light become sensible, by subjecting the air to sudden compression in a glass condenser—water by the moisture deposited by a mass of air, when suddenly cooled, &c.

Such is the composition of atmospheric air, which is so indispensable to respiration, and consequently to the support of animal life.

Upon analyzing a portion of air, which issues from the lungs in expiration, it is found that the proportion of its elements has undergone a considerable change; and this change is found to consist in an increase of the carbonic acid, a diminution of the oxygen, and the addition of a large quantity of watery vapour, containing some animal matter in solution. Thus, instead of consisting of twenty or twenty-one parts of oxygen, seventy-eight of azote, and one or two of carbonic acid, like atmospheric air, the air of expiration contains only about fourteen per cent. of oxygen; its carbonic acid is increased to about eight per cent., or according to Dr. Apjohn only to about 3.6 per cent.; while the proportion of its azote remains nearly unaltered. It appears then, that the portion of air, which has been employed in respiration, loses about seven per cent. of oxygen, and acquires about an equal quantity of carbonic acid, while the quantity of its azote undergoes little or no change.* Now, if it be admitted that the volume of carbonic acid, which is formed by respiration is exactly equal to that of the oxygen which has disappeared, it suggests a very simple theory of the changes which the air undergoes in respiration. As carbonic acid is formed by a combination of carbon and oxygen, and as a certain volume of oxygen gas disappears in respiration, and its place is supplied by an

* It appears to be owing to the increased proportion of carbonic acid, rather than to the loss of oxygen, that air, which has been respired, loses its fitness for respiration. According to Lepelletier, it appears from experiments, that an air composed of forty per cent. oxygen, forty-five of azote, and fifteen of carbonic acid, will not effect hematosis, though it contains twice the proportion of oxygen which exists in common air.

equal volume of carbonic acid, it seems natural to infer, that the air introduced into the lungs has furnished the oxygen, and the blood in the lungs, the carbon, of which this carbonic acid is composed. According to this view, the whole of the oxygen which has disappeared, is still present in the air of respiration, but it exists in a state of chemical union with carbon, under the form of carbonic acid.

It has been ascertained, however, by the researches of Lavoisier and Seguin, of Davy, and more recently by those of Dr. Edwards, that a quantity of oxygen disappears in respiration, which exceeds what is necessary for the formation of the carbonic acid which is generated. Edwards estimates this excess of oxygen consumed in respiration above the volume of carbonic acid formed, when at its maximum, at nearly one-third of the oxygen which has disappeared, and as varying from this almost down to nothing. The variation of this excess depends on a variety of circumstances, as the age, the species, or the peculiar constitution of the animal employed in the experiment.

Now if it be true that more oxygen is consumed in respiration than can be accounted for by the carbonic acid which is formed and is present in the air of respiration, it must be supposed that a part of the oxygen, at least, which has disappeared, has been absorbed by the lungs, while the remaining part may be supposed to have combined with the carbon of the blood, to form carbonic acid. But if a part of the oxygen is actually absorbed by the lungs, some physiologists have been disposed to believe that the whole of it is, and that the carbonic acid expired is not formed by a union of oxygen and carbon in the lungs, but is secreted and ready formed from the blood. This opinion is adopted by Dr. Edwards, and is corroborated by some of his experiments. He found that if frogs, in the month of March, were confined for eight hours in pure hydrogen gas, after their lungs were exhausted of air by pressure, they continued to breathe, though less and less vigorously, and expired a volume of carbonic acid gas nearly equal to their own bulk.* Similar results were obtained in experiments upon kittens. A kitten three or four days old, was placed in a receiver filled with pure hydrogen gas, and in nineteen minutes, performed about an equal number of inspirations. Upon afterwards examining the air contained in the receiver, it was found to contain twelve times as much carbonic acid as could be accounted for by the air contained in the lungs of the animal at the beginning of the experiment.

Edwards's experiments also proved that nitrogen is sometimes

* Rudolphi, however, is of opinion, that the carbonic acid, produced by a frog contained in a globe of hydrogen gas, is not exhaled from the lungs, but from the skin.

absorbed in respiration, or at least, that a variable proportion of this principle disappears in this process; a fact which had been previously asserted by Cuvier and Davy. Edwards found, also, that when small birds were immersed in a large quantity of air for a limited time, there was in many instances, an evident increase in the quantity of nitrogen, while in others, there was a loss of this principle. He observed, that these different results had some connexion with the season of the year, when the experiments were performed. In winter, a deficiency of azote was observed in the air respired, but in spring and summer, the quantity of this principle was found to be increased. Edwards inferred from his experiments, that both absorption and exhalation of azote are constantly going on in the lungs during respiration, and that, according to the predominance of one or the other of these processes, or their exact equality, there is a deficiency or excess of azote in the air expired, or the volume of this principle remains unaltered.

The quantity of air received into the lungs in inspiration is exceedingly variable, and has been very differently estimated by different physiologists. Gregory estimated it at only two cubic inches. According to Rudolphi, the naturalist Abildgaard states of himself, that with a small chest he inspired, in ordinary respiration, three cubic inches of atmospheric air; but about every sixth or seventh inspiration, his breathing was deeper, and he inspired from six to seven, and sometimes even fifteen cubic inches. Herthold, with a more capacious chest, inhaled, in every act of respiration, from twenty to twenty-nine cubic inches; while Keutch inspired only from six to twelve. Goodwyn estimates the volume of air inspired at about fourteen cubic inches; Davy, at from thirteen to seventeen; Cuvier, at sixteen; Allen and Pepys, at sixteen and a half; Menzies, at 43.77. It is estimated by late observers, that the greatest quantity of air, which can be drawn into the lungs in forced inspiration, is about seventy cubic inches. It is not probable, that the air inspired reaches at once the ultimate ramifications of the bronchia. The air-cells are constantly filled with a certain quantity of air, left by preceding inspirations. It is probable that the air last inspired, is mixed by degrees with the residual air present in the cells, and that it serves to keep this in a fit state to arterialize the blood. The quantity of air contained in the lungs after an ordinary or a forced *inspiration*, and after an ordinary or a forced *expiration*, has been differently estimated. According to Berthold, the lungs of an adult, after a forced inspiration, contain about two hundred and fourteen cubic inches of air; after a common inspiration, one hundred and twenty cubic inches; after a common expiration, one hundred and six cubic inches; and after a forced expiration, only eighty-five. Mr. Dalton found that after a forced inspiration, he

could blow out two hundred cubic inches of air from his lungs. His ordinary inspirations and expirations amounted each to about thirty cubic inches.

Menzies says, that many men are able, after ordinary expiration, to expel seventy cubic inches more from their lungs. He thinks from this, that the lungs can hold two hundred and nineteen cubic inches, and, after a common expiration, still contain one hundred and seventy-nine cubic inches.

Allen and Pepys estimate the quantity of air, contained in the lungs after an ordinary expiration, at only one hundred and three cubic inches. They state, as the results of their experiments, that the lungs of a man of common size, contain, after death, more than one hundred cubic inches of air. Rudolphi thinks, that Allen and Pepys's estimate of the volume of the air respired, may be admitted as correct, in ordinary respiration; and in women and children, that it may be lowered. But between the ordinary acts of respiration he observes, there occur, from time to time, fuller inspirations and expirations; and in healthy labouring men, with capacious chests, he thinks Menzies' estimate not too high.

In four subjects, who died natural deaths, and of course *after expiration*, Goodwyn found that the lungs contained severally one hundred and twenty; one hundred and two; ninety; one hundred and twenty-five cubic inches of air. The average of these is one hundred and nine.

In the lungs of hanged persons, who *inspire deeply* before death, he found, in one case, two hundred and seventy-two; in another two hundred and fifty; and in a third, two hundred and sixty-two cubic inches of air.

It is said that we can expel one hundred and seventy cubic inches of air by forced expiration, and that one hundred and twenty cubic inches will still remain in the lungs. If this be true, the volume of air, which these organs contain in their quiescent state, must be the sum of these two quantities, or two hundred and ninety cubic inches.

Now if it be assumed that we inhale forty cubic inches in inspiration, the whole volume of air, which the lungs contain in a distended state, is three hundred and thirty cubic inches, and consequently only one-eighth of the contents of the lungs is changed by every act of respiration. But if we inhale only about fifteen cubic inches in ordinary respiration, which is probably near the truth, the quantity of air contained in the distended lungs is three hundred and five cubic inches, and only about one-twentieth part of their contents is changed in every act of respiration. Such is the uncertainty, however, that reigns on this subject, that some physiologists are of opinion, that the air in the lungs is completely renewed in four acts of respiration. The volume of the air inhaled in every act of respiration is diminished in the lungs

about one-eightieth part of its bulk. If we inspire forty cubic inches, one half cubic inch disappears; a loss which, perhaps, is occasioned by the absorption of a quantity of oxygen, above what is necessary for the production of the carbonic acid which is formed in respiration.

If an adult inhales forty cubic inches of air in inspiration, he must inspire eight cubic inches of oxygen gas. If one-fifth of this be consumed in respiration, one and three-fifths cubic inches of oxygen gas disappear in every act of respiration. If, then, we respire twenty times a minute, we must consume thirty-two cubic inches of oxygen gas in the same time. It is probable, however, that forty-cubic inches is much too high an estimate of the volume of the air inspired in ordinary respiration. If we assume it at fifteen cubic inches, which is not far from the average of several estimates made by different observers, it will follow that, if the quantity of oxygen consumed by respiration in a minute is thirty cubic inches, one half of that which is inspired disappears in every act of respiration. For fifteen cubic inches of atmospheric air contain three cubic inches of oxygen. If half of this, i. e. one and a half cubic inches, disappear, and we respire twenty times a minute, we shall consume thirty cubic inches in the same space of time. Davy estimates the quantity of oxygen consumed in a minute by respiration at 31.6 cubic inches. This would amount to nearly two thousand cubic inches in an hour, and forty-five thousand cubic inches in twenty-four hours. According to Lavoisier and Seguin, a man consumes in an hour, one cubic foot of oxygen, or in twenty-four hours, two pounds, one ounce, and one grain.

The quantity of carbonic acid discharged in every act of respiration, is very variable. By Goodwyn it is estimated at eleven per cent. of the whole volume of air expired; by Menzies, at only five per cent.; by Davy and Gay-Lussac at three or four; by Coutanceau at six or eight. Allen and Pepys estimated the quantity of carbonic acid emitted from the lungs of a healthy man, in ordinary unexcited respiration, at 26.6 cubic inches at the temperature of 50°. They also found that in a pigeon confined in oxygen gas, the production of carbonic acid was only half as great as when it breathed common air; and the loss of oxygen was exactly equal to the united volumes of carbonic acid and *nitrogen* which were disengaged. When the bird was placed in a mixture of oxygen and hydrogen gases, rather more carbonic acid was formed than in common air, and its volume was found to be exactly equal to the loss of the oxygen. The hydrogen was considerably diminished, but its loss was supplied by an equal volume of nitrogen. These experiments then prove, that nitrogen may be secreted and hydrogen absorbed by the lungs.

The quantity of carbonic acid which is formed by respiration

in twenty-four hours, is estimated at seventeen thousand, eight hundred and eleven grains, which would contain about five thousand grains, or nearly eleven ounces of carbon. This, in a year, would amount to about two hundred and fifty pounds solid carbon excreted from the body by the lungs. This estimate, however, there is reason to think, is much too high. Prout supposes that the conversion of *albuminous matter* into *gelatin* is one of the principal sources of the carbonic acid which is expelled from the lungs in respiration, and which he supposes to exist in the venous blood. Gelatin contains three or four per cent. less of carbon than albumen, and it enters into the structure of every solid part of the body, but exists neither in the blood, nor in any other of the animal fluids. The skin, especially, consists almost wholly of gelatin; a fact, from which Prout conjectures that a large part of the carbonic acid of venous blood is formed in the skin, and in the other gelatinous tissues. Accordingly, we find that the skin gives off carbonic acid, and consumes oxygen.

The consumption of oxygen and the production of carbonic acid, are extremely variable under different circumstances, even in the same person. Whenever respiration is very active, more oxygen is consumed, and more carbonic acid formed. More carbonic acid is formed during digestion and during exercise; animal food and wine, and mental agitation increase it. According to Nysten, more carbonic acid is formed by respiration, in inflammatory fevers, and less, in atonic diseases. If pure oxygen gas be respired, a larger quantity of oxygen is consumed, and more carbonic acid expired, than in the respiration of atmospheric air. More carbonic acid is formed during the day than in the night. The maximum quantity is formed between eleven o'clock, A. M. and one o'clock, P. M.; the minimum, about eight o'clock in the evening; from which time until half past three in the morning, there is no change.

The air expired from the lungs is loaded with a large quantity of watery vapour, derived partly from the lungs, and partly from the mouth, fauces, and trachea. The quantity of it was estimated by Hales, at about twenty ounces in twenty-four hours; more recently by Menzies, at six; by Abernethy, at nine; and by Thomson, at nineteen ounces.

The breath frequently becomes impregnated with the odour of substances which have been swallowed. If odoriferous substances are injected into the veins, or a serous cavity, the breath acquires this odour. If a solution of phosphorus in oil, be injected into the veins of an animal, its breath becomes luminous in the dark, and in the light is loaded with dense white fumes of phosphoric acid. In fact, it appears an important function of the lungs, to act as an excretory organ for the venous blood. Hence these organs perform an important part in the process of assimilation and nutri-

tion, not merely in effecting the necessary exchange of principles between the component parts of the inspired air and those of the venous blood, but also by depurating the blood from unassimilable substances of the volatile kind, taken with the food, or otherwise introduced into the system. It is manifest therefore that the pulmonary vapour must be exceedingly variable, according to the nature of the food, drink, and medicines, which have been taken, and also according to the condition of the vital actions, and the variable circumstances of health and disease. Thus musk, the juice of garlic, alcohol, camphorated spirits, sulphuret of carbon, injected into the veins, become sensible by their odour in the pulmonary vapour almost immediately.

Vital part of Respiration.

By the vital part of respiration, is meant the changes produced in the blood by the influence of atmospheric air. The lungs digest air, as the stomach digests food; and, as the digestion of food is designed to form a nutritive fluid, the blood, out of aliment received into the stomach, the digestion of air contributes to the same object, the formation of blood. It completes what the stomach had begun. The nutritive fluid, formed by the stomach and its appendages and carried into the blood-vessels, is still imperfect until it has passed through the lungs and received the influence of respiration. In the lungs it is supposed to lose a large quantity of carbon under the form of carbonic acid, and to absorb oxygen from the air, and to acquire its peculiar scarlet colour; and it then becomes adapted for all the purposes of life, and not before. The organization of the blood is probably completed in the lungs, perhaps by the addition of the red colouring matter, or hematosine. Respiration is therefore essential to the formation of the blood, which is the great excitant of the system, the fluid which keeps all the machinery of life in action, and which supplies the materials out of which all this machinery itself is manufactured. This is one essential purpose of respiration.

Another, equally important, and indeed closely connected with the first, is to produce certain changes upon the blood already formed, after it has circulated through the system, and been employed in the various functions of life. While the florid arterial blood is administering to the various operations of life, it is gradually changing its colour, and becoming darker, and at last, what remains of it, assumes the purple colour of venous blood. In this condition it is no longer fit for the purposes of the animal economy. It is robbed of the principles most essential to life, and it must be renewed and prepared afresh, before it is fit to be employed again. For this purpose it is returned from all parts of the body to the heart, by the veins, and instead of being again

transmitted to the various parts of the system by the arteries, it passes into the lungs, having received, just before its entrance into the heart, a supply of fresh prepared nutritious matter, the chyle, mixed with the result of the vital decomposition of the organs and tissues of the system, part of which is probably designed to be remoulded again into the living tissues, and part to be eliminated from the system by the various excretions. In the lungs it loses a large quantity of carbon, and watery vapour, and perhaps absorbs oxygen, and is changed back to its former scarlet colour, and is then again fitted for the uses of the animal economy.

The coloration and perhaps arterialization of the blood, however, requires other conditions than the mere contact of atmospheric air. It has been ascertained that the saline substances existing in the serum are necessary to this effect. A variety of salts, as chlorate of potash, nitre, common salt, and bicarbonate of soda, have the property of communicating to the blood a florid colour, far brighter than that of arterial blood. A solution of one of these substances, of the proper strength, will give to venous blood the arterial colour, even without exposure to the air. A clot of venous blood, if its serum be carefully removed, is not made florid by oxygen gas; and arterial blood, deprived of its serum by pure water, assumes the dark colour of venous blood. Hence it appears that the arterialization of the blood depends on two causes, essentially different, viz. the influence of the oxygen of the atmosphere, and the effect of the saline substances contained in the serum.

A curious fact suggested by this subject is that the blood taken from a vein is sometimes of a very dark purple, and at others of a bright florid red, very similar to arterial blood. From this also it seems probable that the coloration of the blood is influenced by other causes than respiration. Another circumstance which I have repeatedly noticed is, that in some instances the florid blood issues from the veins with great impetuosity, and even a pulsatory motion, resembling very nearly a jet of arterial blood.

Dr. Christison was led to the conclusion that the coloration of the blood in respiration is a chemical process, from finding that when venous blood acquires the arterial colour by agitation with atmospheric air, a considerable portion of oxygen disappears and carbonic acid is formed.

From what has been said it appears that respiration, in relation to its influence upon the blood, is a complex function. It completes the formation of the new blood; it renovates the old, preparing it again for the purposes of life; and it reconverts into blood the molecules detached from all the organs by vital decomposition, and which have consequently existed, at least once before, under the form of blood. It incorporates the worn-out

venous blood, both with matter imperfectly animalized, and with matter animalized to excess, and combines the heterogeneous mass into one homogeneous fluid highly impregnated with vitality, arterial blood.

Theory of Respiration.

There is still much difference of opinion among physiologists in regard to the mode in which the changes produced in the blood are effected by respiration.

An opinion, which prevailed for some time, assumed that the oxygen of the air inspired, combines in the lungs with the carbon of the venous blood, and that the latter is converted into arterial blood by the loss of this carbon. This opinion was founded on the fact that the volume of carbonic acid formed in respiration, is almost exactly equal to the oxygen which disappears; and as carbonic acid contains its own volume of oxygen gas, it was inferred that the oxygen which disappears is converted into carbonic acid, by combining with carbon in the lungs. This carbon Mr. Ellis supposed to be separated from venous blood by a kind of secretion.

Another opinion which has been maintained by several distinguished physiologists is, that the oxygen is absorbed by the blood, and the carbonic acid is gradually formed in the course of the circulation, and is afterwards exhaled by the venous blood in a subsequent act of respiration. As the quantity of oxygen gas which disappears is rather greater than sufficient for the production of the carbonic acid which is formed, it must be supposed that at least a part of the oxygen consumed is absorbed by the blood; and if so, it seems probable that the whole of it is, and consequently, that the carbonic acid is not formed in the lungs at the expense of this oxygen, but is exhaled, ready-formed, from the venous blood. A consideration which affords some confirmation to this opinion is, that the inhalation of oxygen is not necessary to the production of carbonic acid, as was ascertained by the experiments of Dr. Edwards on frogs and kittens;—for these animals, when confined in hydrogen gas, exhaled carbonic acid. Nysten and Coutanceau, also, after inhaling azote, found in the air of expiration seven or eight per cent. of carbonic acid, just as when common air is respired. It is possible, however, as Rudolphi supposes, that this carbonic acid was formed from the atmospheric air present in the lungs at the time of the experiments. Edwards's experiments, also, seem to have ascertained the fact, that the blood circulating in the lungs is capable of absorbing oxygen as well as hydrogen and azote; and Nysten found that oxygen gas might be injected into the veins of dogs

without injury, provided but small doses were injected at a time; while the injection of azote and hydrogen soon occasioned death. Some experiments of Girtanner seem to establish the presence of oxygen in arterial blood. He put some arterial blood of sheep under a receiver filled with pure azote; and at the expiration of thirty hours, the air in the receiver contained oxygen enough to support the combustion of a candle about two hours.*

That carbonic acid exists in venous blood, seems to be rendered probable from the fact that carbonic acid may be injected in considerable quantity into the veins without injury. An experiment of Darwin has a bearing upon this subject, in proving that gaseous substances may probably exist in the blood in a state of loose combination. He found that venous blood, when exposed in an exhausted receiver, swelled to ten times its original bulk.

On this subject, however, physiologists are not agreed. Tiedemann and Gmelin found that no carbonic acid nor any other permanent gas was extricated from blood taken from the femoral artery and vein of a dog, and placed in different tubes under the receiver of an air-pump. Arterial blood, however, was found to *absorb* carbonic acid pretty largely.

Upon adding vinegar to each kind of blood, which as before was placed under a receiver, a quantity of carbonic acid escaped from both, but more from the venous than from the arterial. Whence it followed, that combined though not free carbonic acid exists in the blood.

The conclusions of these physiologists on the nature of changes in respiration, were: That the oxygen is absorbed by the blood, and combines partly with carbon and hydrogen, forming carbonic acid and water, and partly unites with the solid organic compounds contained in the blood. From these proceed acetic or lactic acid, which combines with a portion of carbonate of soda contained in the blood, and expels its carbonic acid into the cells.

The acetate of soda thus formed loses, in its course through the different secreting organs, its acetic acid, and the soda combines again with carbonic acid, in its passage through the body with the mass of the blood, and again returns to the lungs in the form of carbonate of soda.

This view supposes that acetic acid is formed by respiration, and that this acid expels from the alkaline carbonate of the venous blood a portion of its carbonic acid, converting it into an acetate.

Another very plausible theory of respiration assumes that the oxygen is absorbed by the radicles of the pulmonary veins; and that the carbonic acid and watery vapour are exhaled from the

* Lepelletier.

pulmonary mucous membrane. But the exhalation of aqueous vapour and of carbonic acid is not regarded as peculiar to the lungs, and of course not as the essential and characteristic part of respiration; because the skin is constantly performing precisely the same office; since the matter of insensible perspiration contains both aqueous vapour and carbonic acid combined with some animal matter. The exhalation of carbonic acid in respiration is not necessarily connected with the absorption of oxygen. Like other secretions, it is supposed to be formed from *arterial*, and not *venous* blood; to be secreted, not from the venous blood of the pulmonary artery, but from the branches of the bronchial arteries, distributed over the mucous membrane of the bronchia. While the essential and characteristic part of respiration is supposed to consist in the absorption of oxygen by the radicles of the pulmonary veins. In this view the air drawn into the lungs in respiration is decomposed; part of its oxygen is absorbed into the venous blood, and changes it to arterial. The roots of the pulmonary veins are the instruments of this absorption, and bring the oxygen into immediate contact with the venous blood. The carbonic acid, and the aqueous animal vapour, which exist in the air expired, are the product of a secretion from the mucous membrane of the bronchia, a secretion from arterial blood, and perfectly similar to the exhalation from the skin. This secretion is not supposed to have any influence upon the arterialization of the blood in the lungs, because being formed from arterial blood, the effect of it should rather be to convert this into venous, as is the case with the other secretions, than to change the venous into arterial blood. The lungs, in this view, are the seats of two opposite functions, absorption and exhalation. By the first, an aerial principle, necessary to life, is incessantly introduced into the animal economy, and constitutes the great and essential purpose of respiration. The *pulmonary* capillary system is the seat of this absorption. The second, which has its seat in the *general* capillary system, and which consists in the exhalation of carbonic acid, and a watery vapour, with a little animal matter from the lungs, is not peculiar to these organs, but is shared equally by the skin.

It may not be amiss to notice in this place the theory of Chaussier, who supposes that the oxygen is absorbed by the lymphatics of the lungs, vessels with which these organs are very abundantly supplied; that it is conveyed by the lymphatics into the thoracic duct, and there blended with the chyle and lymph; and afterwards, in combination with these fluids, conveyed to the right side of the heart, and thence transmitted to the lungs; and that it is in the extreme divisions of the pulmonary artery that the combination becomes perfect. The change of colour of the blood in the lungs, his theory supposes to be occasioned merely by the separation of carbonic acid already existing in the venous blood. This theory,

it will be perceived, transfers the process of hematosis from the lungs to the thoracic duct. It assumes that the oxygen, before combining with the blood, passes through a great extent of the absorbent system, besides a part of the circulating, which is inconsistent with the suddenness of the change which takes place in the blood in respiration. The venous blood acquires *instantly* the arterial colour in the lungs—as was demonstrated by an experiment of Bichat. It also assumes that the coloration of the blood in the lungs is occasioned by the exhalation of carbonic acid. Now, according to Coutanceau, during the respiration of any other gas than oxygen, especially of azote, the exhalation of carbonic acid and watery vapour continues, yet the venous blood retains its dark colour.

Influence of Innervation upon Respiration.

The external organs of respiration, the nose, the mouth, the muscles about the chest, the diaphragm, and the abdominal muscles, are supplied with nervous influence by the fifth pair of nerves; the facial, the accessory, the spinal nerves, and the phrenic; while the proper organs of respiration, the larynx, the trachea, and its ramifications, constituting the mass of the lungs, are supplied by the pneumogastric nerve, and the pulmonary plexus, which is formed by filaments of the pneumogastric nerve, and the anterior branches of the first thoracic ganglions.

The pneumogastric nerves, as might be inferred from their supplying all the internal organs of respiration with branches, exert an important influence upon respiration, though it still remains a subject of controversy with physiologists, what the precise nature of this influence is. The section of these nerves, on both sides, about the middle of the neck, soon occasions extreme dyspnœa, followed in a few hours by death; and, on dissection, the lungs are found in a state of great engorgement with blood, and the bronchial tubes filled with a white frothy fluid.

Death, in these cases, is owing to a paralysis of the muscles which open the glottis, while those which close this aperture remain unaffected. The *dilating* muscles of the larynx receive their nerves from the inferior laryngeal, or the recurrent branch of the pneumogastric; the constrictors, from the superior laryngeal. The section of this nerve paralyzes the constrictors, and the glottis remains open; while the section of the recurrent branch paralyzes the dilators, and the glottis remains closed. It is said that the section of the recurrent nerve, or that of the pneumogastric, between the superior and inferior laryngeal nerves, is more dangerous than the division of the par vagum, in the neck.

If, after the section of the pneumogastric nerve, an opening be

made in the trachea, so as to admit the air freely into the lungs, the dyspnœa is relieved, and life may be prolonged for three or four days. Yet the animal inevitably dies from increasing dyspnœa, sometimes accompanied with vomiting. The blood in the arteries assumes a darker colour, and, according to Mr. Brodie, less carbonic acid is evolved in respiration. Upon dissection, the lungs are found engorged with dark blood, and the bronchial cells and tubes, and frequently the trachea itself, are filled with a frothy, and sometimes bloody fluid. In some cases there is also an effusion of serum, or blood, in the parenchyma of the lungs.

Different opinions have been entertained respecting the manner in which asphyxia is produced by the section of the par vagum. It may be owing to one of two causes. Either the division of these nerves prevents the penetration of air into the bronchial cells, or it prevents the mutual action of the blood and air upon each other, and consequently, the arterialization of the blood. This latter opinion is adopted by Dupuytren, who thinks that animals die after the division of these nerves, because the air, though it still penetrates freely into the lungs, and comes in contact with the blood, is unable to combine with this fluid, since this combination requires the vital action of the pneumogastric nerves. He endeavoured to establish this opinion by experiment. He found that if an artery in an animal in which the par vagum was divided, were opened, the blood, which at first spirted out of the bright arterial colour, gradually became darker, and assumed the appearance of venous blood. The compression of the nerves produced the same effect. Legallois found that an opening into the trachea, after the section of the pneumogastric nerves, did not prevent the arterial blood from becoming venous, though it permitted the free ingress of air into the lungs.

Dumas, however, found that if air were forced into the lungs after the section of the par vagum, arterial blood continued to be formed; from which he inferred that, in this experiment, asphyxia is occasioned by some obstruction to the entrance of air into the lungs; so that without some external force this fluid is unable to penetrate into the bronchial cells. The fact that after decapitation life may be maintained for some time by artificial respiration appears to be irreconcilable with Dupuytren's opinion.

A fact stated by Magendie deserves to be noticed in this place. From his experiments, it appears that the section of the *vagi* destroys the coagulability of the fibrin, a property which he regards as indispensable to life.

The most probable opinion, on the whole, seems to be that of Brachet, viz. that the division of the par vagum annihilates the appetite of respiration, and paralyses the fibres of the bronchia; permitting an accumulation of the bronchial secretions in the cells

and fine tubes of the lungs, and thus gradually preventing the contact of the air with the blood in the pulmonary vessels.

The experiments of Brachet appear to prove, that the pneumogastric nerves convey from the lungs to the brain a knowledge or sentiment of the want of respiration, in consequence of which the brain reacts upon the external muscles of respiration, by means of the cerebro-spinal nerves distributed to these muscles; and upon the muscles and fibrous coat of the larynx, trachea, and bronchia, through the medium of the pneumogastric.

Brachet, in some of his experiments, found that the section of the par vagum, appeared to annihilate the appetite for respiration. In one of these, after the division of these nerves in a puppy three days old, he plunged the muzzle of the animal into warm water, so as entirely to prevent the entrance of air into his lungs. The animal made an effort to raise his head out of the water, and died in a state of asphyxia, after a few slight motions, which were wholly unlike the struggles for breath of a suffocating animal. The muzzle of another puppy of the same litter, was in like manner plunged in water, without the previous division of the par vagum. Unlike the first, he made violent efforts to withdraw his nose from the water and to respire, and the asphyxia came on with difficulty, and was accompanied with convulsive struggles.

In two other comparative experiments, two puppies of the same litter were placed under two receivers, filled with atmospheric air, one of them having previously undergone the section of the pneumogastric nerves, and had an opening made in the trachea; the other without any preparation. In the latter, respiration soon became larger and more frequent, the animal raised his head, and breathed with his mouth open and his nostrils expanded, and died with the symptoms which usually accompany this kind of asphyxia. The former, in which the par vagum had been divided, breathed in the usual manner, and died quietly at the expiration of forty-six minutes, without agitation, and without expanding his nostrils or opening his mouth.

From these experiments Brachet infers, that the section of the par vagum intercepts the impression produced by the privation of atmospheric air, in its passage to the brain; since one animal which has been subjected to this experiment, dies of asphyxia without manifesting any feeling of the want of respiration. The continuation of the movements of respiration, after the appetite has been annihilated, Brachet attributes to the habit which the respiratory muscles have acquired of contracting, and which survives the sentiment of the want of respiration. The convulsive struggles which sometimes occur in this kind of asphyxia, he attributes to the influence of the black blood on the heart and other organs.

Brachet also attempts to establish, that the par vagum apprises the brain of the presence of mucus, or any foreign substance in the bronchia, and that by means of the same nerves, the fibres of the bronchia react upon and expel these substances. He divided the two pneumogastric nerves in a dog, and then made an opening into the trachea, through which he introduced a little ball of orris (boule d'iris) fastened to a thread. The breathing became laborious, but the animal exhibited no sign that he experienced any disagreeable sensation. He then held an open jar of muriatic acid to the opening in the trachea for several minutes, and even let some drops of it fall into the interior of it, but without eliciting from the dog any signs of sensation.

In another experiment, he made an opening in the trachea of a dog without dividing the par vagum. A few drops of blood fell into the trachea and excited coughing. The ball of orris excited violent coughing, which pushed it forcibly towards the larynx. The muriatic acid occasioned paroxysms of coughing, which obliged him to withdraw it. On applying it again, the cough was renewed—upon which Brachet divided the par vagum, when the cough suddenly ceased, respiration became rattling, and in less than an hour, the dog died without having expectorated any thing.

That these nerves react upon the fibres of the bronchia, causing them to contract, Brachet endeavours to prove by experiment. He injected warm water into the trachea of a dog, which excited violent coughing, by which the water was expectorated. The irritation, however, provoked an abundant secretion, which kept up the cough and expectoration for several hours. Upon repeating the experiment, the next day, on the same dog, the same phenomena occurred; but after the dog had apparently ejected all the water from his lungs, Brachet divided the par vagum, upon which expectoration immediately ceased, respiration became rattling, and in about two hours the dog died.

Lepelletier also remarks, that the section of the *par vagum*, or a suspension or diminution of its power, causes a debility or inaction of the air vesicles, and a stagnation in them of the air altered by hematosis; and it explains the occurrence of asphyxia in certain cases, where the great phenomena of inspiration and expiration continue to be carried on. For the air may continue to be renewed in the principal divisions of the bronchia, by the mechanical movements of respiration; but its renovation in their ultimate branches, is impossible without the vital contraction of the air vesicles themselves.

CHAPTER XVI.

THE NUTRITIVE FUNCTIONS.

The nutritive functions are four in number, viz. *Digestion, Absorption, Secretion*, and *Nutrition.*

Digestion.

Digestion is a function peculiar to animals; and the existence of a separate set of organs devoted to digestion, has been regarded as one of the characteristics by which animals are distinguished from plants. Vegetables, it is true, are nourished and grow; but they do not, properly speaking, *digest.* Their nutrition and growth are the result of an external absorption from the atmosphere and the soil, effected at their surface, and by means of roots; while animals first receive the materials of their nutrition into a central cavity, where they are subjected to a series of remarkable changes, and their nutritive elements are *afterwards* carefully selected, and imbibed by a set of *internal* roots. Nutritive matter, therefore, is absorbed in a crude state by plants; but in a digested state, by animals. In vegetables, and the lowest orders of the animal kingdom, the absorbing vessels themselves exercise an assimilating power over the matters absorbed as nourishment, and this preparation is the only digestion which the food of these kinds of organized matter undergoes; but in all the animal kingdom, with the exception of the very lowest orders in the zoological scale, digestion is centralized in a particular apparatus, more or less complicated, according to the position of the species in the scale of animal life.

In its simplest or rudimental state, the digestive apparatus consists of a membranous sac, provided with a single opening, which serves both for mouth and anus. In its first stage of complication, it assumes the form of a straight canal, the length of which is less than that of the animal to which it belongs, and is provided with *two* orifices, one destined for the reception of the food, the other to the expulsion of the refuse matter of nutrition. In its higher stages of complication, it progressively acquires a greater relative length, in some of the higher orders of animals exceeding, by nearly thirty times, the length of the body, and presenting numerous convolutions. Its two orifices are guarded by circular muscles, which act under the control of the will;

and several auxiliary organs are connected with it, which contribute to give greater variety and complication to its functions.

In the *mammalia*, the digestive canal presents its greatest or last degree of complication. In the human species it consists of a tube about six times as long as the body, extending from the mouth, through the chest and abdomen, to its inferior orifice, the anus; unequal in its diameter, being much larger in some places than in others, and in one part swelling out into a capacious sac; presenting, in a great part of its course, irregular convolutions, and terminating at each extremity by one orifice, closed by a circular muscle, which acts under the control of the will.

The digestive canal is found partly in the head, where it forms the cavity of the mouth; partly in the neck and thorax, where it takes the names of the *pharynx* and the *œsophagus;* but principally in the abdomen, where it forms the stomach and intestines, which, with the associated viscera, the liver, the pancreas, the spleen, and the mesentery, occupy nearly the whole of this great cavity.

The mouth is formed by the two lips. Its cavity is bounded above by the palate, below by the tongue, before by the teeth, laterally by the cheeks, and posteriorly by the curtain of the palate, which separates the cavity of the mouth from the *pharynx.* The pharynx is a funnel-shaped cavity, which terminates in the *œsophagus.* It opens into the mouth by the isthmus of the fauces; into the nasal cavities by the posterior nares; into the trachea, by the superior opening of the larynx; and into each ear, by a funnel-shaped canal, called the *Eustachian tube.* The *œsophagus,* or gullet, is a continuation of the pharynx. It is a long, straight, fleshy tube, which passes down the chest, behind the trachea, lying upon the vertebral column; and it opens into the stomach by an orifice which is called the *cardia.* The pharynx and œsophagus, or the pharyngo-œsophageal cavity, is the organ of deglutition.

The stomach is a large pouch, situated below the diaphragm, and lying obliquely across the epigastric region, and a part of the left hypochondriac. Above, it is bounded by the liver and the diaphragm; below, by the transverse colon; behind, by a part of the vertebral column, and the great centre of the ganglionic nerves; before by the false ribs of the left side, with their cartilages; on the left, by the spleen.

The stomach has two orifices, a superior and an inferior. By the former, which is also called the *cardiac,* it communicates with the œsophagus; by the latter, also termed the *pyloric,* it opens into the first of the small intestines, or the *duodenum.* Two curved lines, a superior and an inferior, extend from one of these orifices to the other. The superior, which is concave, is much shorter than the inferior, which is convex; i. e. the inferior arch

of the stomach is much greater than the superior. The situation of the organ, as well as its volume, varies much, according to its state of emptiness or repletion. When empty, it is flaccid and depending, and its greater curvature inclines downward. But when distended, its greater curvature is raised forward. The stomach is the organ of *chymification*, or gastric digestion.

The intestines extend from the pylorus to the anus, forming a mass of convolutions, which fill most of the abdominal cavity. They are usually divided into two portions, viz. the large and the small intestines; a distinction founded on their relative diameters. The small intestines, or the upper portion, are subdivided into three parts, viz. the *duodenum*, the *jejunum*, and the *ileum*. The first receives its name from its length, which is equal to twelve fingers' breadths. It is the seat of *chylification*, or duodenal digestion. The *jejunum*, or hungry gut, is so called from its being generally found empty; and the *ileum*, i. e. the twisted gut, derives its name from the numerous convolutions which it exhibits. The small intestines have a less diameter and thinner coats than the other portions of the intestinal canal; but their length is much greater, amounting in an adult to four or five times the length of the whole body. They are attached to the superior lumbar vertebræ by a duplicature of the peritoneum, called the *mesentery*. The large intestines commence where the small terminate. A circular fold of the mucous membrane of the ileum, penetrating by its free border into the large intestine, and called the ileo-cæcal valve, separates the two great divisions of the intestinal canal from each other. The large intestines are divided into three portions, viz., the *cæcum*, the *colon*, and the *rectum*, which last terminates in the anus.

In the greater part of its extent, the digestive canal consists of three membranes, viz. a mucous, a muscular, and a serous. Only the two first, however, are essential to it; the mucous, or internal tunic, constituting a secreting and absorbing surface; and the muscular, or middle, executing the various motions to which the food is subjected after its reception into the mouth. The external, or serous tunic, is merely accessary, as it is wanting in many parts of the digestive tube, and no where completely envelopes it.

The soft parts of the mouth are composed almost wholly of muscles, lined internally by a mucous membrane. These muscles execute the different motions of the mouth, by which this cavity is enlarged or diminished, and variously modified in its shape, in the processes of mastication and insalivation, and the food is afterwards forced from the mouth into the pharynx. The membrane which lines the mouth secretes a mucus which lubricates this cavity, and is blended with the food in mastication.

The muscular part of the pharynx is composed of six con-

strictor muscles, which contract this cavity and compress its contents, forcing them into the œsophagus in the act of deglutition. The fibres of these muscles form planes or sheets, which cross each other in various directions. The pharynx is lined internally by a mucous membrane of a deep red colour.

The œsophagus, in like manner, is composed of a muscular coat and a mucous membrane. The former consists of two strata of muscles, viz. one external, which is composed of longitudinal fibres, of considerable thickness and strength; and one internal, consisting of circular fibres, considerably thinner than the former. Near the stomach the longitudinal fibres diverge, and may be traced extending over its cardiac extremity; but the circular fibres wholly disappear at the termination of the œsophagus. The mucous membrane is continuous with that which lines the pharynx. It presents numerous longitudinal folds, which are owing to the contraction of the muscular coat.

According to Magendie, the inferior third of the œsophagus, is subject to an uninterrupted alternate motion of contraction and relaxation. The contraction commences at the upper part of the inferior third, and proceeds, with a certain degree of rapidity, to the insertion of the œsophagus into the stomach. Its duration is variable, but on an average amounts to about thirty seconds. The part thus contracted is hard and elastic, like a tense cord. The relaxation which succeeds, takes place suddenly and simultaneously in the contracted fibres. This motion of the œsophagus is under the influence of the par vagum. If these nerves are divided in an animal, the œsophagus ceases to contract in the manner just described, and assumes a state intermediate between contraction and relaxation.*

The œsophagus is furnished with mucous follicles, which are sparingly distributed over it.

The stomach, also, is composed of two principal coats, or membranous laminæ. The internal is a soft, spongy, mucous membrane, which is extremely vascular, or plentifully supplied with blood-vessels. Except when the stomach is distended, the mucous membrane is drawn into folds or wrinkles, so that its surface is much greater than that of the other coats. It is smeared with mucus, secreted by numerous follicles, seated in its mucous coat.

The second coat of the stomach is muscular, and is composed of fibres disposed in three different directions, viz. longitudinally, circularly, and obliquely. The longitudinal fibres form the exterior muscular plane. Immediately beneath this are the circular fibres, which run parallel to one another; and subjacent to the latter are the oblique, which form broad fasciculi at the two

* Magendie.

extremities of the stomach. Besides these two principal coats, the stomach receives an external tunic, formed by a duplicature of the peritoneum. This coat is united to the muscular, by cellular tissue.

The stomach is plentifully supplied with blood-vessels and nerves. The blood is chiefly designed to furnish materials for the secretion of the gastric fluid, which is supposed to be the principal agent in chymification. The arteries of the stomach are very large and numerous, and they all spring, directly or indirectly, from a large trunk called the cœliac artery. The nerves of the stomach originate from both nervous systems, the cerebro-spinal and the ganglionic. From the former it receives branches by means of the pneumogastric; and from the latter, by the cœliac plexus.

The structure of the intestines resembles, very nearly, that of the stomach. They are composed, essentially, of two coats, viz. a mucous and a muscular; the former constituting a secreting and absorbing surface; the latter, or muscular, executing the various motions, which are necessary in propelling the contents of the intestines regularly through the canal. There is a third tunic, which is external, and which is derived from the peritoneum. This is termed the serous, or peritoneal coat.

The mucous coat is sometimes termed *villous*, from the villosities which its internal surface exhibits, resembling the pile of velvet. These villi are extremely numerous, presenting the appearance of small spongy masses, adhering to the mucous coat. They are very vascular, and their bases are surrounded by small bodies of a glandular structure, termed mucous follicles, which are destined to secrete the mucus which smears the inner surface of the intestines.

The mucous coat of the small intestines is gathered into folds or plicæ, presenting when dried a lunated appearance and denominated the *valvulæ conniventes.* These appear to be designed to increase the internal surface of the intestines, and to retard the passage of the alimentary matter, so as to give more time for the necessary changes to be wrought upon it, and also for its absorption by the lacteals.

The muscular coat consists of two orders of fibres, one longitudinal, or running parallel to the axis of the canal; the other circular, or embracing it like rings. In the large intestines, the longitudinal fibres are collected into bundles, or fasciculi, which have the effect of puckering up the intestines, forming numerous prominent cells, in which feculent matter is sometimes retained a long time.

The arteries of the intestines are derived from the mesenteric arteries; their nerves almost wholly from the solar plexus. Into

the first of the small intestines, the duodenum, open the excretory ducts of two important glands, the liver and the pancreas.

The necessity of taking food arises from the losses which the body is constantly undergoing by the different secretions and excretions, and which amount to several pounds in the space of twenty-four hours. These losses immediately affect the blood, which becomes impoverished by the demands upon its principles, which nutrition, and the various secretions and excretions, are constantly making. But, indirectly, the solids feel the effects of this incessant drainage, because they are undergoing, without intermission, the process of organic decomposition, and the molecules detached from them, are passing into the venous blood, and are afterwards eliminated from the system by the urinary and other excretions.

We are incited to take food by certain internal sensations, which are termed hunger and thirst. Neither the seat nor the efficient causes of these sensations are well known. Hunger has been frequently referred to a peculiar affection of the nerves of the stomach; an opinion which in itself seems sufficiently probable, as sensation is a phenomenon of the nervous system, and as the sensation of hunger is referred directly to the stomach. The experiments of Brachet, in which the section of the pneumogastric nerves appeared to annihilate the appetite for food, tend to corroborate this opinion. It is observed, however, by Mayo, that nausea is referred to the stomach upon the same grounds with the sensation of hunger; and yet, according to the experiments of Magendie, nausea and retching may be produced after the removal of the stomach of an animal, by injecting tartar emetic into the veins.

Thirst has been referred to a certain impression upon the nerves of the fauces and pharynx. But in the case of a man who had cut through the œsophagus, several buckets full of water were swallowed daily, and discharged through the wound, without quenching the thirst,—which was afterwards allayed by injecting spirit, diluted with water, into the stomach. From these facts Mayo observes, that it is not impossible, that a person might be hungry without a stomach, and thirsty without a throat.

Digestion, from the first reception of aliment into the mouth, to the rejection of the refuse of it, by the inferior extremity of the intestinal canal, is composed of the following processes, viz. 1. *manducation* and *insalivation*, performed by the mouth; 2. *deglutition*, by the pharynx and œsophagus; 3. *chymosis*, by the stomach; 4. *chylosis*, by the duodenum; 5. intestinal *absorption*, by the small intestines; and 6. *defecation*, by the large.

I. *Manducation* is the mechanical division of the food, which is broken and ground down by the action of the teeth, pressed

against it by the motions of the jaws. These motions are of three kinds, viz. one vertical, consisting in the elevation and depression of the lower jaw, and two horizontal, in one of which the lower jaw is moved backwards and forwards, and in the other laterally, or from side to side. These motions are executed by the action of several muscles, viz. the temporal, the masseter, the external and internal pterygoid, the zygomatic, the digastric, and some others. The temporal, masseter, and internal pterygoid muscles, elevate the lower jaw, the temporal moving it somewhat backwards as well as upwards; the masseter, forwards and upwards; and the pterygoid, from side to side. In carnivorous animals, these muscles, particularly the temporal, possess prodigious power. The lower jaw is moved horizontally forward, by the combined action of the two external pterygoid muscles, aided by the masseter and the internal pterygoid. The pterygoid muscles, when they act singly, move the jaw obliquely, from side to side, and communicate a grinding motion to the teeth.

The lower jaw is depressed, and the mouth thus opened, by the action of several muscles, especially the digastric, and various others, attached to the os hyoides.

During the operation of mastication, in which the food is divided and ground down by the teeth, it is intimately penetrated and impregnated with the saliva, a fluid which is secreted by three pairs of glands, viz. the parotids, the submaxillary, and the sublingual. These glands are stimulated to an increased secretion of saliva by the taste or smell, and frequently by the mere idea, of food. These glands will be described hereafter.

The quantity of saliva secreted during an ordinary meal, is probably very considerable. In a case of division of the œsophagus, described by Dr. Gairdner, from six to eight ounces of saliva were observed to be discharged during a meal, which consisted of broth, injected into the stomach through the wound. Under the stimulus of mastication, as Mayo remarks, the quantity secreted is probably much greater.

The minute division of the food by mastication, and its penetration by the saliva, appear to be designed, chiefly, to promote its solution in the stomach, and to facilitate deglutition. Hence, a leisurely and sufficiently prolonged mastication, in general, renders digestion easier and more prompt.

II. *Deglutition.* After the morsel is sufficiently masticated, it is pushed into the pharynx by the action of the tongue, which is raised and pressed against the palate by the *stylo-glossal* muscles. At the same time, the pharynx is drawn upwards to receive the morsel by the action of the muscles, which raise the *os hyoides*, and by the *stylo-pharyngeus.* The pharynx is embraced by the fibres of three muscles, which are termed its upper, middle, and lower *constrictors;* the contraction of which tends to diminish its

cavity and to compress its contents; and their successive action gradually forces the bolus into the œsophagus. Its return into the mouth is prevented by the pressure of the tongue; its entrance into the posterior nares is precluded by the velum pendulum palati, which is forced before the bolus, and becomes horizontal and tense by the action of the *levator* and the *circumflexus* of the palate; and its passage into the larynx is prevented by the epiglottis, which is pressed down by the food upon the orifice of the larynx. According to Magendie, however, the epiglottis is not necessary to deglutition; for, in some of his experiments, it was removed from animals, and it has sometimes been destroyed by disease in the human subject, without materially impairing deglutition. The passage of food into the larynx, according to Magendie, is prevented by the action of the muscles which close the *rima glottidis,* viz. the *arytænoideus transversus,* and the *arytænoidei obliqui.* As long as these muscles preserve their power of contraction, food is prevented from passing into the larynx, even in the absence of the epiglottis. But if the power of contraction in these muscles be destroyed or enfeebled, as appears to be the fact in some cases of palsy, deglutition is liable to be interrupted by violent fits of coughing, occasioned by the entrance of a part of the food into the larynx—although the epiglottis remains entire. The secretions of the mouth and fauces, the saliva to dilute the aliment, the mucus to lubricate the surfaces over which it is to pass, are almost indispensable to the deglutition of dry substances. It has been observed that the use of belladonna occasions in some instances, so great a diminution of the salivary and mucous secretions, that the individual is unable to mould dry substances, such as bread, into a bolus, and can with difficulty swallow them.

As soon as the food has reached the œsophagus, the muscular contraction of this fleshy tube is excited, by means of which the bolus is gradually forced into the stomach. The power of gravitation contributes but little to the descent of food into the stomach; for it is found that funambulists can swallow without difficulty, with their heads downward. The motion of the œsophagus in deglutition, consists in a successive contraction of its circular fibres, from above downwards. The upper part of the tube is dilated by the bolus, which is forced into it by the contraction of the pharynx. Its superior circular fibres are then excited to contract, and the food is pushed further down into the tube, dilating the parts immediately beneath, which react upon it, and force it still further down, until it reaches the stomach. The longitudinal fibres, in contracting, shorten and relax the œsophagus, and in this mode promote the descent of its contents. Mayo supposes that the longitudinal fibres of the two extremities of the alimentary canal, viz. the œsophagus and the rectum, are de-

signed to strengthen these parts, and to prevent their elongation and rupture by the volume of their solid contents.

Deglutition is divided by Magendie into three stages, viz. 1. The passage of the food from the mouth into the pharynx. 2. From the pharynx into the œsophagus. And, 3. From the œsophagus into the stomach. The first stage is voluntary; the second partakes of the nature both of voluntary and involuntary action. Magendie considers pharyngeal deglutition as involuntary; yet Mayo remarks, that it may at any time be performed by a deliberate exertion of the will. The third stage, or œsophageal deglutition, is removed from the jurisdiction of the will. Yet, as Mayo remarks, the œsophagus appears to partake of the nature of both the voluntary and involuntary muscles; for when the nervi vagi are pinched, a *sudden* action ensues in its fibres, which is presently after succeeded by a second action of a slower kind.

III. *Chymosis.* Gastric digestion, or chymosis, consists in the conversion of food in the stomach into a soft pulpy mass, termed *chyme.* The aliment, previously masticated and thoroughly blended with the saliva, descends through the pharynx and œsophagus into the stomach, in the manner just described. Some physiologists suppose that the stomach is not mechanically distended by the mass of the aliments, but that it exercises the power of self-dilatation in the reception of the food. However this may be, the organ enlarges in proportion to the volume of the food which is swallowed. Its coats are distended, the plicæ of its mucous membrane are unfolded, and the sinuosities of its arteries and veins disappear. The increased volume of the stomach pushes the diaphragm up into the thorax, distends the walls of the abdomen anteriorly, and presses against the contiguous viscera, particularly the liver and spleen. The position of the stomach undergoes a change, the organ performing, as it were, part of a revolution on its axis, by which its anterior face becomes superior, its posterior inclines downward, its inferior arch is raised forward, and its superior turned backward.

Motions of the Stomach.

The stomach, stimulated by the presence of food, reacts upon and compresses it; for being a hollow muscular organ, it contracts upon its contents, and under some circumstances with very considerable force. It has been ascertained by observation, that the human stomach is capable of contracting to such a degree, as to expel from its cavity hairs, needles, and other smaller bodies. The fleshy stomachs of birds possess vastly greater mechanical powers, so as even to be able to break down very hard substances. The muscular action of the stomach consists of a

kind of vermicular motion, produced by the alternate contractions of its transverse and longitudinal fibres, the former diminishing its diameter, the latter shortening its length, by approximating its splenic and pyloric extremities. Tiedemann and Gmelin remark, that the muscular coat of the stomach does not contract simultaneously throughout its whole extent, but one part contracts a little, while another dilates, and *vice versâ;* the place where contractions take place becoming thicker and rugous. According to the same physiologists, these undulatory movements proceed from the œsophagus towards the pylorus, and from this back again to the œsophagus. In some cases, they observed these motions to begin at the same time at both extremities of the stomach, and to meet at the middle of the organ. They appeared to be most energetic in the pyloric part of the stomach, where the muscular coat is thickest. Hence the motions of the stomach during digestion have a predominant tendency towards the pylorus. Dr. Beaumont found that the bulb of a thermometer introduced into the stomach during this period, was drawn down with a considerable and steady force. The most vigorous contractions are occasioned by the most stimulating food. These successive contractions of the muscular fibres occasion a slow movement of the aliments in the stomach, by which they are brought successively into contact with all parts of its surface, and thoroughly penetrated with the gastric fluid.

According to Beaumont, the contractions of the muscular coat of the stomach produce a constant slow revolution of the food round the interior of the organ, from one extremity to the other. After its entrance into the stomach, the ordinary course of the food, in these revolutions, is first from right to left, along the small arch, thence, along the large curvature, from left to right. "The bolus, as it enters the cardia, turns to the left, passes the aperture, descends into the splenic extremity, and follows the great curvature towards the pyloric end. It then returns in the course of the smaller curvature, makes its appearance again at the aperture, in its descent into the great curvature, to perform similar revolutions."* From one to three minutes are occupied in completing one of these revolutions. During these motions, the cardiac and pyloric orifices of the stomach are closed, so as to prevent the escape of the food. The contraction of these apertures continues, even if the stomach be cut out of a living animal, during digestion. According to Home, the stomach, during these contractions, forms a kind of double sac, by the action of a *transverse* band, situated three or four inches from the pyloric extremity. The contraction of this band during digestion, divides the sac of the stomach into two parts, one of which, viz.

* Beaumont.

the splenic, contains the food that is but little digested; the other, or *the pyloric*, that part of it which is further advanced in chymification. This opinion, Beaumont's experiments confirm.

Besides the active motion of the stomach, this organ is subjected to the alternate movements of the abdominal muscles and the diaphragm in respiration. That these motions may afford some aid to the organ in executing its functions, is the more probable from the fact that weak stomachs are frequently assisted by the mechanical support of a belt.

Secretions of the Stomach.

Not only the muscular action of the stomach is excited by the stimulus of food, but its circulation and its secretions are increased. There is a concentration of vital activity in the organ, an increased afflux of blood towards it, a greater evolution of heat, and an increase of its follicular and perspiratory secretions. The latter of these, the gastric fluid, is exhaled in abundance, and the process of digestion commences.

In the process of chymification the food undergoes a remarkable change; for the properties of chyme are entirely different from those of the aliment out of which it is prepared. The taste, smell, and other sensible properties of the food, are altered or disappear, and new ones are acquired. It is evident, therefore, that the chemical affinities of the food have been totally subverted, and its elements have entered into new combinations. Whether this change is confined to the proximate principles of the food, or extends to its ultimate elements, it is not easy to determine. This remarkable change in the properties of the food is produced by a fluid secreted by the stomach, called the gastric liquor. This fluid is secreted abundantly during digestion, but not when the stomach is empty. It has already been observed that the stomach is largely supplied with blood-vessels. It receives much more blood than is necessary for its own nutrition; and the destination of this excess of blood, probably, is to furnish materials for the secretion of the gastric fluid. The gastric liquor is produced not by a follicular secretion, but arterial exhalation. Like all the other secretions, it may be increased, diminished, or changed in its qualities by various causes. Thus the division of the pneumogastric nerves, the use of narcotics, the excessive use of stimulating drinks, violent emotions of the mind, &c. diminish the secretion of this fluid; and, on the other hand, condiments and high-seasoned food increase it.

The gastric fluid, according to Beaumont's observations, is a clear transparent fluid, perceptibly acid to the taste, and a little saltish, but destitute of odour. It effervesces slightly with the alkalies; possesses in a high degree the property of coagulating albumen, and is powerfully antiseptic. According to Beaumont,

pure gastric fluid will keep unchanged for almost any length of time; and it appears from Spallanzani that meat may be preserved in it without taint for five or six weeks, or even longer. Its acid properties are owing to the presence of free muriatic and acetic acids. According to Tiedemann and Gmelin, the gastric fluid contains the hydrochloric and acetic acids, and, in horses, the butyric; saliva, osmazome, chloruret, and sulphate of soda, and a little carbonate and phosphate of lime. The degree of its acidity corresponds to the less or greater digestibility of the food; those aliments which are the most difficult of digestion causing a greater degree of acidity in the gastric fluid. Thus bones, cartilages, fibrin, concrete albumen, meat, gluten, oats, and bread, are more difficult to digest than starch, potatoes, rice, gelatin, and liquid albumen; and they were found to occasion the secretion of a more acid gastric fluid in dogs and cats. In horses, oats caused the secretion of very acid gastric liquor. It appears, then, that the degree of acidity of this fluid depends on the degree of excitation of the stomach, produced by the food. The gastric liquor appears to be secreted only when the stomach is excited by the stimulus of aliment; and, consequently, no conclusion respecting its properties, can be drawn from experiments on the fluid, taken from the stomach during fasting, as this consists chiefly of gastric mucus, mixed with saliva; a consideration which may account for many contradictory results in the researches of physiologists on the gastric fluid.

This fluid appears to be the principal agent in chymification or gastric digestion. Its most remarkable property is its power of dissolving alimentary substances; a power which it retains some time after death; for alimentary matter introduced into the stomach of an animal recently killed is more or less perfectly digested. The powers of the gastric fluid in dissolving alimentary substances were first satisfactorily ascertained by some experiments performed by Spallanzani and Stephens, in the last century. Stephens in his experiments inclosed various alimentary substances in hollow metallic balls pierced with holes, to admit the gastric fluid; and he found that the balls, when voided by stool, were empty, the substances they had contained being digested, having escaped by the holes in their sides. These experiments were performed on men and other animals. Spallanzani obtained similar results; and pursuing the idea, he exposed certain aliments, properly masticated and impregnated with saliva, to the action of the gastric fluid *out of the stomach.* They were kept in the axilla for several hours; and upon examination afterwards were found to be chymified. Beaumont's experiments appear to establish, conclusively, the power of the gastric liquor in dissolving alimentary substances out of the stomach. The process is rather slower perhaps, because the

exact temperature of the stomach cannot be accurately maintained by artificial means, and because it is impossible to subject the food to the same mechanical agitation, by exactly imitating the motions of the stomach. The results, however, are in both cases apparently the same; the chyme, prepared by artificial digestion, presenting the same sensible properties as that which is found in the stomach. The solvent powers of the gastric fluid in respect to alimentary matter are very great. The hardest bones are dissolved and digested by it in the stomachs of dogs; and Beaumont found that it would dissolve even bones out of the body. It coagulates milk and the serum of the blood, and other kinds of albumen; and afterwards dissolves the coagula. The energy of this menstruum appears to observe an inverse ratio to the mechanical powers of the teeth and stomach, employed in the comminution of the food. Hence in animals which masticate their food, or are possessed of thick fleshy stomachs, the gastric fluid is endued with feebler powers; while in those which are destitute of teeth and have membranous stomachs, its solvent energy is very great.

But these extraordinary properties of the gastric fluid are exerted almost exclusively upon organic substances. And it is a remarkable fact that these substances, when endued with life, effectually resist its power. Hence the living walls of the stomach itself, and intestinal worms which sometimes ascend into the stomach, are invulnerable to the action of this fluid.

The powers of the gastric liquor, as might be supposed, are adapted in every species of animal to the nature of the food on which it subsists. Hence the gastric fluid of herbivorous animals will digest only vegetables; and that of carnivorous animals only animal substances. A curious example of this is furnished by the fact that when a hawk or an owl has swallowed a small bird having seeds in its stomach, these have passed unaltered through the intestines of the bird of prey. Its properties, however, are susceptible of essential modification, by the qualities or nature of the substances employed as food,—so that herbivorous animals may by degrees become accustomed to, and even thrive upon, animal food, and *vice versâ.* This change however is always gradual, and hence the danger or inconvenience at least, of making sudden changes in the nature of the food.

The solvent properties of the gastric fluid appear to be only a special example of a general assimilative power possessed by the animal fluids. Thus animal substances, even bones introduced into the abdomen of a living animal, or inserted under the cuticle, in some instances are wholly dissolved.

A temperature of about 98° or 100° is very favourable to the solution of the food in the gastric fluid. Beaumont found that while a phial of this fluid, at a temperature of 99°, completely

dissolved a portion of masticated fresh beef, the same quantity in another phial in which an equal weight of chewed beef was placed, and exposed to a temperature of 34° in the open air, had in the same time produced only a macerated or softened appearance in the beef.

According to Lenhossek, the animal temperature is raised during digestion, and the region of the stomach becomes a kind of focus of heat. Hence taking food diminishes the danger of freezing in persons exposed to severe cold. In most of Beaumont's experiments, however, the temperature of the stomach was not raised by digestion; but in two or three of them it was somewhat increased. The ordinary temperature of the stomach is about 100°, and Beaumont, in some instances, found it to be higher at the pylorus than at the cardiac extremity.

During digestion a small quantity of gaseous matter is usually present in the stomach, which is found to consist of oxygen, carbonic acid, hydrogen, and azote. Sometimes it is wholly absent. Some of it is probably derived from the air swallowed with the food; but a portion of it doubtless is extricated during the changes which the aliment undergoes in the stomach.

The solvent powers of this secretion, in relation to alimentary substances, may be understood, in part, by a reference to its composition. Thus the water which it contains dissolves several simple alimentary principles, as liquid albumen, gelatin, osmazome, sugar, gum, and starch. The hydrochloric and acetic acids, dissolve several other principles, which are not soluble in water; as concrete albumen, fibrin, coagulated caseum, gluten, and gliadine, a substance analogous to gluten. These acids dissolve, also, cellular tissue, membranes, tendons, cartilages, and bones. Their solvent power is assisted by heat; and hence, the temperature of the stomach is an important agent in gastric digestion. From the fact that alimentary substances, when subjected to the action of the gastric fluid out of the stomach, are converted into a substance presenting the characters of chyme, some physiologists have embraced the opinion that gastric digestion is nothing but a chemical solution of the aliment in the gastric fluid. Tiedemann and Gmelin, who adopt this opinion, admit however, that with respect to some alimentary substances, a peculiar kind of decomposition is produced by the action of the gastric fluid. Starch, for instance, when dissolved in the stomach, loses its peculiar property of giving a deep blue colour to iodine, and is converted into sugar and gum.

It would follow, from this theory of digestion, that the digestibility of aliments is in proportion to the facility with which they are dissolved in the gastric liquor, and of course depends upon their peculiar composition. The substances most easy of digestion are such as are soluble in warm water, or contain a large

proportion of soluble principles, as sugar, gum, liquid albumen, and gelatin. Those which require the aid of acids to dissolve them, as those which contain much gluten, concrete albumen, fibrin, caseum, cartilage, or bone, are of more difficult digestion; while some are insoluble in the gastric fluid, and of course indigestible; as the fibres of wood, or of plants, the skin of some of the leguminous plants, the kernels of fruits, feathers, hairs, &c. Chymification, however, is not to be regarded merely as a chemical solution of alimentary matter in the gastric fluid. It is true that the process of gastric digestion may be imitated out of the body, by macerating alimentary substances in the gastric fluid. No doubt a solution more or less perfect may be effected in this way, by the solvent powers of this fluid over substances of an alimentary kind. This is established by the experiments of Spallanzani, and more fully by those of Beaumont. But it is not so certain that they become endued with all the properties of chyme, especially with those which assimilate them to the nature of the living animal body, by undergoing this process. It is indeed difficult to conceive how a mere *chemical* solution of aliment can endue it with living properties, or *vitalize* it; for undoubtedly chyme is in the first stage of animalization. It cannot become invested with living powers, if placed out of the *atmosphere* of vitality. Vital affinity can operate only within the sphere of vital power. If then the gastric fluid is a mere chemical solvent of alimentary substances, it seems probable that the living coats of the stomach, with which all parts of the food are brought successively into contact, may impart to the latter certain properties, which may assimilate it to the nature of the living organization; properties which it is impossible to conceive that it can acquire, when removed from the contact of living matter. Life is a unit; its properties cannot be separated from the source whence they originate. It is as impossible to conceive of bottling up a portion of vitality with a few ounces of gastric fluid, as it would be to think of corking up a phial of sunshine, and keeping it in the dark.

The analysis of digestion, proposed by Prout, corresponds in the main with this view. Prout attributes to the stomach, three distinct powers; which are all exerted in digestion; viz. a *reducing*, a *converting*, and a *vitalizing* power. By the reducing power he means the faculty which the stomach possesses of dissolving alimentary substances, or of bringing them to a semifluid state. This operation he supposes to be altogether chemical. By the converting power of the stomach, he means the faculty of changing simple alimentary principles into one another, as starch into sugar and gum. Without such a power, Prout thinks that the uniformity in the composition of the chyle, which he supposes to be indispensable to the existence of animals, could not

be preserved. This process of *conversion* he considers, also, as chemical, but as of more difficult accomplishment than the reducing. The vitalizing, or *organizing* power, is that by which alimentary substances are brought into such a condition as adapts them for an intimate union with the living body. This power, he says, cannot be chemical, but is of a vital character, and its nature is entirely unknown. The vital properties which the chyme acquires in the stomach, whatever these properties be, it is the prerogative of the living or the nervous powers of the stomach to confer. The influence of these powers in digestion is illustrated by numerous facts, especially by the influence of those medicinal agents which depress the nervous energy, as opium and other narcotics; the effect of passions of the mind, and the sudden accession of disease; and intercepting the nervous influence by the ligature, or section of the par vagum; causes which can hardly be supposed competent to destroy the chemical or solvent powers of the gastric fluid, but which, nevertheless, are well known by physiologists, to interrupt or weaken the process of gastric digestion.

The substance into which aliment is converted in the stomach is called *chyme*. This is a semifluid, homogeneous matter, of a grayish colour, sourish smell, and insipid or disagreeable taste, but varying considerably in its sensible properties, according to the qualities of the food out of which it is prepared. According to Beaumont, it is invariably homogeneous, but its colour partakes slightly of the colour of the food. "It is always of a lightish or grayish colour, varying in its shades and appearance from that of cream to a grayish or dark-coloured gruel. It is, also, more consistent at one time than at another; modified in this respect, by the kind of diet used. It is invariably distinctly acid." Its acidity, according to Tiedemann, is derived from that of the gastric fluid. Leuret and Lassaigne, found the chyme in an epileptic, who died five hours after taking food, to present the appearance of a pale saffron-coloured pap, of a strong and repulsive smell, containing lactic acid, a white crystalline animal matter, similar to sugar of milk; a fat yellowish acid matter, resembling rancid butter; another animal substance, like caseum; albumen, phosphate of lime, muriate and phosphate of soda.

According to Raspail, chyme is a kind of paste formed of a mixture of the *debris* of the vegetable and animal tissues used as food, and of a solution in acetic acid of albumen, gum, and oil, together with all the salts existing in the tissues, which the acetic acid can dissolve. The acidity of the chyme, therefore, is due, as he asserts, not as Prout supposes, to the presence of the hydrochloric, but to that of the acetic acid, which he says may be obtained abundantly from the chyme by distillation. This acetic acid is derived, not from the gastric fluid, but from the fermenta-

tion of alimentary principles in the stomach. Raspail remarks that gastric digestion requires the presence and the mutual action of at least two substances, viz. sugar, or a substance convertible into sugar, and albumen or gluten. When a mixture of these two principles is left to itself, they react upon each other, and become the subject of an intestine motion, called fermentation. The result of this mutual action is alcohol, which remains in the liquid, and hydrogen and carbonic acid, which escape with effervescence in the form of gas. If a portion of gluten remains after the disappearance of the sugar, a new reaction takes place between this residual gluten and the alcohol, and the result of it is the formation of the acetic acid, at the expense of the two elements of this new fermentation. The acidity of the chyme then in this view is developed by fermentation, and is derived, not from the muriatic, but the acetic acid.

The acetic acid thus developed holds in solution or renders soluble the vegetable gluten or animal albumen and oil, which may still be present in the alimentary mass. If we suppose this solution of albumen, &c. in acetic acid to be sufficiently diluted with water to assume a liquid form, and to be separated from the *debris* of the tissues used as food, it would represent, according to Raspail, an acid and rudimentary blood, requiring only to be rendered alkaline by the action of the bile to be converted into chyle, a fluid which differs in its composition from blood only in the absence of colouring matter.

The carbonic acid and hydrogen gases extricated during the gastric fermentation, Raspail supposes to be absorbed by the walls of the stomach.

The time required for the conversion of food into chyme, varies according to the greater or less degree of digestibility of the latter. In Beaumont's experiments, the average time employed in gastric digestion was about three hours and a half. If the food is of a soft consistence, and well divided by mastication, it is speedily penetrated by the gastric fluid, and rapidly dissolved. But if it possesses a certain degree of consistence, or has been swallowed in large masses, its solution goes on slowly, and from the surface to the centre. The external layers are frequently softened, and almost dissolved, while the parts within are almost wholly unchanged. Those parts of the aliments which are nearest the surface of the stomach, are most exposed to the action of the gastric fluid, as well as to the vitalizing influence of the stomach, and of course are the soonest dissolved, and chymified.

By the successive contractions of the muscular coat, the dissolved portions are carried towards the pylorus, and gradually pass out of the stomach into the duodenum. The passage of the chyme from the stomach takes place during the expansion of the

circular fibres of the pyloric extremity, perhaps by the contraction of the longitudinal. It is at first slow, but becomes more rapid in the later stages of chymification, as the formation of chyme becomes more abundant. According to Rudolphi, the chyme passes out of the stomach by drops, and the more rapidly as the degree of its fluidity is greater.

The sensibility of the pylorus appears to bear a strict relation to the digested condition of the food; so that any undigested portion, which happens to approach this outlet of the stomach, is denied an exit. The pylorus contracts so as to prevent its escape. Hence food of difficult digestion may be retained in the stomach a considerable time, as for example, even a week or more, and then be vomited up unchanged, or pass off by stool. For a similar reason, chyme is always present in the greatest quantity at the pyloric end of the stomach, whither it is regularly carried as fast as it is formed. While at the cardiac end, where digestion commences, it is found much more sparingly. In general, the peristaltic action of the stomach continues until the aliment is wholly dissolved by the gastric fluid, and has passed out of the stomach. The organ then resumes a state of contraction and quiescence natural to it when empty. Fluids pass out of the stomach very speedily, chiefly perhaps by absorption.

Influence of Innervation upon Chymification.

That the par vagum or pneumogastric nerve exercises some important influence over digestion, has long been known to physiologists, though it is not yet fully ascertained what this influence is. The results of experimental researches on the uses of these nerves, by different physiologists, have not been uniform, but sometimes directly contradictory. But it seems to be pretty generally agreed, that the division of these nerves in the neck causes a suspension of the process of digestion.

Blainville passed a ligature round the nerve above the lungs, and the effect was a suspension of respiration and chymification. The ligature was afterwards withdrawn, and the two functions were restored. The same physiologist and Legallois, performed the experiment on pigeons; and it was found that the corn swallowed by the birds remained unaltered in the crop. Dupuy performed a similar experiment on horses. The animals ate and drank, but died on the sixth day; and on dissection no chyle was found in the lacteals. These experiments have been performed by several other physiologists, with similar results.

The functions which have been ascribed to the pneumogastric nerve, by different physiologists, in relation to gastric digestion, are of three kinds.

1. That it presides over the secretion of the gastric fluid.

2. That it animates the muscular motions of the stomach and œsophagus.

3. That it is the seat of sensation in the stomach, bestowing upon this organ both common sensibility, and the appetites of hunger and thirst.

The first opinion is adopted by Philip and Brodie, and, to a certain extent, by Tiedemann and Gmelin. Brodie found that in animals killed with arsenic, after the section of the pneumogastric nerves, no trace of gastric fluid could be discovered in the stomach. Philip referred the suspension of digestion after the division of these nerves, in his experiments upon animals, to a suspension of the secretion of gastric fluid. Tiedemann and Gmelin ascribe the check which digestion experiences from the section of these nerves, to a paralysis of the muscular coat of the stomach; but they are also of opinion, that the secretion of the gastric fluid, and its acid qualities, are dependent on the influence of these nerves; and hence, that the division of them may retard digestion, by preventing the secretion of this fluid, as well as by paralysing the muscular fibres of the stomach. The formation of this acid secretion out of the blood, which is an alkaline fluid, they suppose, requires an energetic action of the nervous power on the blood, which penetrates into the capillary network of the stomach; and they conjecture that this influence operates by causing a decomposition of the salts contained in the blood, viz. the muriates of potash and soda, and the acetate of soda, the acids of which, they suppose, are secreted into the stomach, freed from their bases, and become integrant parts of the gastric fluid. This opinion is founded on an experiment, in which the stomach of a dog in which both pneumogastric nerves had been divided with a loss of substance, and which had afterwards eaten the boiled white of eggs, exhibited no mark of acidity, its contents not reddening the tincture of turnsole. It seems probable, however, that the branches of the great sympathetic, which penetrate with the arteries into the coats of the stomach, have a very considerable, if not the principal share, in the secretion of the gastric fluid.

2. Breschet inferred from his experiments, that digestion is retarded by the section of the par vagum, not in consequence of a suspension of the secretion of gastric fluid, but by a paralysis of the muscular fibres of the œsophagus and stomach, resulting from this operation; in consequence of which, the mechanical motions of the stomach, necessary to chymification, are no longer executed, and the food lies motionless in the hollow sac. Breschet found that this operation retards but does not destroy digestion.

Leuret and Lassaigne also performed the experiment on a horse, by cutting out a piece from the vagus four or five inches

long, on each side of the neck; and then performing tracheotomy to prevent asphyxia, they suffered the animal to eat. They found, however, that the œsophagus was paralysed by the operation, and the food forced back into it and vomited up. To prevent this they tied the œsophagus, and eight hours after the animal had eaten, it was killed; and they found that digestion had taken place, and the food was completely chymified. The experiment was afterwards repeated with the same results; and the conclusion which Leuret and Lassaigne drew from it was, that digestion may take place independently of the par vagum. In fact, the vagus spends most of its inferior branches upon the œsophagus, sending but few to the stomach, which is supplied with nerves from the ganglionic system; and hence, the section of the vagus only *retards* digestion, which is still carried on under the influence of the great sympathetic.

It is a curious fact, that the influence of the pneumogastric nerves on digestion may be supplied by galvanism and electricity, and even by mechanical irritation. If the nerve be merely divided, and the ends be suffered to remain in contact with each other, digestion is not suspended. The two ends must be removed from each other, or a piece cut out, to insure the effect; and in that case, if the inferior or gastric end of the divided nerve, be stimulated by a galvanic current, or even by mechanical irritation, digestion recommences. From this fact, Breschet inferred that electricity operates in restoring digestion by exciting the muscular movements of the walls of the stomach, by means of which the food is brought successively into contact with all parts of its inner surface; and that mechanical irritation operates on the same principle. This view is strikingly corroborated by a fact mentioned by Tiedemann and Gmelin, viz. that they had frequently witnessed, in experiments, that mechanical and chemical irritations, applied to the pneumogastric nerves, occasioned contractions in the muscular coats of the stomach.

3. Experiments make it probable, that the stomach derives cerebral sensibility from the par vagum; and that the sense of hunger also depends on the influence of these nerves.* Bell states, that animals killed by acrid poisons die without pain, if the par vagum be divided, but howling with agony if these nerves are left uninjured. The section, or the compression by ligature, of these nerves, a little above the stomach, appears wholly to destroy the feeling of hunger. Brachet divided the pneumogastric nerves in a dog which had been kept from food twenty-four hours, and was ravenously hungry. The animal before the operation was extremely impatient for food, but became indifferent

* Secetur nervus pneumogastricus. Cessat illico fames; non cessat illico digestio. —*Martinii Element. Physiol.*

to it afterwards, and went and lay quietly down. When meat was offered him, he began to eat; and continued to eat till both the stomach and œsophagus became distended with food. The feeling of satiety was evidently annihilated, as well as that of hunger; and the animal ate merely to gratify the sense of taste. Similar experiments on horses, performed by Leuret and Lassaigne, were followed by like results. Two inches of the par vagum were cut out, and the animals continued to eat as before; from which these physiologists inferred, that the appetite was not affected by the division of these nerves. It was remarkable, however, that they continued to eat after the stomach was very much distended with food, a fact which makes it probable that the feeling of satiety was destroyed by the experiment, and the animals continued to eat automatically, as it were, without being prompted by appetite to begin, or by the sense of fulness to leave off. The feeling of thirst also appears to be destroyed, as well as that of hunger and the appetite of respiration. The subjects of these experiments, probably, not only eat but drink also and respire automatically.

It should be remembered, that the pleasure of eating does not consist exclusively in the gratification of the appetite, which resides in the stomach, but that much, if not most of it, is purely gustatory, and is seated in the palate and fauces. The physical incentives to taking food are twofold, having their seats in distinct portions of the alimentary canal, and deriving their origin from separate and independent parts of the nervous system. It is true these are intimately connected together, yet not so closely but that considerable pleasure may be taken in eating when no real hunger exists. Even infants, whose natural tastes have not been corrupted by artificial habits, frequently gorge themselves with their natural food, and are obliged to get rid of the excess by vomiting. There can be no doubt that the same is true, to a certain extent, of the inferior animals, and hence, from the fact that animals continue to eat after the section of the pneumogastric nerves, we cannot infer that the feeling of hunger is not derived from these nerves.

A fact mentioned by Swan may seem to be at variance with this alleged function of the pneumogastric nerve. He relates that in a gentleman who died after suffering great dyspnœa, the par vagum was found to be smaller than usual, and softer in its consistence. This patient had enjoyed a great appetite for several months before his death, but had never felt satisfied with eating, nor experienced any sense of fulness, whatever quantity of food he might have taken.

This case will perhaps be found to prove quite as much for, as against, the sensiferous function of the pneumogastric nerve. The nerve was diseased, and the consequence was, that one

modification of gastric sensibility, the feeling of satiety and fulness after eating, was annihilated or very much diminished; while another, viz. the sense of hunger, was morbidly excited. Either of these affections of the sensibility of the stomach, might have resulted from a diseased state of the nerve, from which this organ derives this property, and who can undertake to say that a certain degree or state of disease in this nerve, might not destroy or diminish one kind of gastric sensibility, and morbidly increase another? It is worthy of remark that Mr. Swan himself attributed both affections to the diminished energy of the nerves. For he says, that it appeared to him that the pneumogastric nerves suffered from the action of the colchicum, of which the patient had made a free use, and I think, he goes on to say, "*the craving for food*, and the want of a sensation of fulness after eating ever so much, showed the nerves at least *had lost their sensitive qualities.*"

The pains which are sometimes experienced in paralysed limbs furnish examples somewhat analogous; for in these cases we have impaired nervous power diminishing one kind of sensibility, and increasing another. Both of the symptoms in Mr. Swan's patient, obviously point to an affection of the instrument of sensation in the stomach, whatever this may be; and the diseased condition in which the par vagum was found, gives probability to the conclusion that this nerve is that instrument itself.

The analogy of the lingual branch of the fifth pair, which bestows common and special sensibility on the tongue, may be alleged in favour of this view of the functions of the par vagum.

It is here proper to mention the assertion of Magendie, that if the section of the pneumogastric nerves be made in the thorax, below the place where the branches which supply the lungs, are given off, the food which is afterwards taken, is regularly converted into chyme, and furnishes abundant chyle; and he is disposed to attribute the suspension of digestion, when the nerves are divided in the neck, to the influence of disturbed respiration upon the action of the stomach. Brachet, however, regards Magendie's experiments inconclusive, on account of the great difficulty of making a complete division of the pneumogastric nerves below the origin of the pulmonary branches, without dividing the œsophagus itself. In his experiments to determine this point, he found that if the complete section of the par vagum was effected by the division of the œsophagus a little above the cardia, the stomach of the animal remained distended with the food taken just before the experiment; a very slight alteration only being perceptible in the contents of the stomach, several hours after the section of the œsophagus.

On the whole, it appears to be established by experiment, that the pneumogastric nerves not only give activity to the muscular

fibres of the stomach and œsophagus, but also bestow cerebral sensibility upon the organ, and are the immediate seat of the sensations of hunger and thirst. It is probable, also, that the secretions of the stomach are influenced by the state of its sensibility, and that the section of these nerves, by impairing or destroying this power, may indirectly occasion a change in the qualities of the gastric fluid, or a diminished secretion of it, and in this manner, likewise, impair or suspend chymification.

It appears, also, that digestion is suspended by other operations by which the nervous power is weakened. Wilson found that chymification was arrested by a section of the spinal cord in the lumbar region; and Edwards and Vavasseur witnessed the same effect, from the removal of part of the cerebral hemispheres. An injection of opium into the veins was found to produce the same effect.

According to Brachet, the *par vagum* is the channel which transmits the impressions of medicinal and poisonous substances from the stomach to the brain. If a narcotic be administered in a sufficient dose, its effect upon the brain is perceived almost immediately, and long before the poison could be digested and absorbed. But if the par vagum be previously divided, the effect is prevented. Brachet gave to each of two dogs six grains of opium, having in one previously divided the par vagum. The dog which had not undergone the operation, fell into a state of profound narcotism, while the other lay down quietly, and manifested no other symptom than the dyspnœa which always results from the section of the pneumogastric nerves. The nux vomica, in like manner, which acts so violently and rapidly as a poison on dogs, produces no such effect if the par vagum be divided. The poison may be given in a double or triple dose, and yet *intoxication* will not be produced at once, as is commonly the case; but will manifest itself at a much later period, with much less intensity than common. Emetics, and purgatives also, administered to dogs which have suffered the division of these nerves, according to Brachet, produce none of their usual effects. This statement, however, it is proper to mention, is at variance with the fact related by Magendie, that tartar emetic, introduced into the stomach of an animal, in which both branches of these nerves had been divided, occasioned vomiting; whence it is inferred that an irritation must have existed in the stomach, implying the presence of some kind of sensibility in the organ, after the section of the par vagum. But if vomiting always implies irritation or sensation of any kind in the stomach, what, it may be asked, is the seat of this sensation, in animals made to vomit by tartar emetic injected into the veins after the stomach has been cut out, and a bladder substituted in its place? If vomiting can occur in one case without the aid of gastric sensibility, it may

in the other; and the effect in both, is doubtless to be referred to the same cause, viz. the introduction of the tartar emetic into the circulation, in the one case by injection, in the other by absorption from the coats of the stomach. The poisonous effects of alcohol are first communicated to the brain through the same channel.

IV. *Chylosis.* The duodenum receives the chyme from the stomach, and has generally been believed to accomplish the second digestion, or the conversion of chyme into *chyle.* In the duodenum it meets with the bile, pancreatic and intestinal fluids, loses its acid properties, and becomes alkaline, probably by the agency of the soda of the bile; and by this change, according to Raspail, it is converted into chyle, and thus advances another step towards the formation of blood, from which it now differs in composition only in the absence of colouring matter. In this state it is greedily imbibed by the coats of the intestines, leaving a residual mass, which is destined, after having been slowly conducted through a very long and winding passage, to be dismissed by the postern of the system. The duodenum, like the other parts of the intestinal canal, is composed of three tunics, viz. a serous or peritoneal, a muscular, and a mucous. The first, however, covers only the anterior part of the intestine, and can hardly be considered as essential to it. The second, or muscular, is formed almost wholly of circular fibres. The third or mucous, exhibits a great number of transverse folds, termed the *valvulæ conniventes.* It exercises a double secretion, one follicular, or mucous, the other perspiratory, or exhaling. The arteries of the duodenum are derived from the right *gastro-epiploic*, and the *splenic;* its nerves, almost wholly from the solar plexus. The situation of the duodenum is deep in the abdomen, on a level with the third or fouth lumbar vertebra; having behind it the vertebral column, the aorta, and the vena cava inferior; before it, the stomach, and transverse mesocolon; above, the liver; and below, the small intestines.

In the duodenum the chyme is exposed to the action of three new agents, by which its nutritious parts are further elaborated, and the constituent principles of chyle are developed. These agents are the intestinal fluid, the bile, and the pancreatic secretion. The irritation excited by the acid chyme on the inner surface of the duodenum, occasions a copious afflux of these fluids into the intestine. According to Tiedemann and Gmelin, the gall-bladder is always empty during digestion, but full during fasting. The pancreatic fluid is secreted in increased abundance; and the stimulus of these two fluids, particularly of the acrid bile, in addition to that of the chyme, produces an increased secretion of the intestinal fluids, both the mucous or follicular, and the aqueous or perspiratory.

The intestinal fluid of the duodenum has some resemblance to the gastric liquor. According to Tiedemann and Gmelin, it is acid in the duodenum and the superior part of the small intestines, though less so than the gastric fluid; and it becomes gradually less and less acid, until at last, in the inferior part of the small intestines, its acidity disappears, and it becomes neutral. The free acid contained in the intestinal fluid is chiefly the acetic; the hydrochloric, which exists in the gastric fluid, being rarely present in the intestinal. The quantity of the intestinal liquor is said to be in proportion to the degree of indigestibility of the food.

The bile is a viscid fluid, secreted by the liver, of a greenish brown colour, extremely bitter taste, and possessed of alkaline properties. It will be more particularly described hereafter.

The pancreatic fluid is a whitish semi-transparent fluid, of a slightly saline taste, and coagulable by heat. It contains a large proportion of albumen and caseine; and, according to Tiedemann and Gmelin, a free acid.

The mixture of these fluids with the chyme in the duodenum, effected by the contraction of this intestine, soon occasions a sensible change in its appearance. After passing the mouth of the *ductus choledochus,* it loses the homogeneous appearance which it presented in the stomach, and becomes more or less deeply coloured with yellow, its central portion presenting a deeper hue than the parts nearer the intestine. The external part adheres to the duodenum, so that its motion through the intestine is less rapid than that of the central portion. The sour smell and taste of the chyme gradually lessen and disappear; and, according to the experiments of Marcet and Prout, albumen, which is an essential part of the chyle, is copiously developed. This substance begins to appear a few inches from the pylorus, and disappears in the inferior portion of the small intestines.

According to Prout, if the food contained no albuminous matter, no albumen is developed in the stomach; but immediately on the entrance of the chyme into the duodenum, and its mixture with the biliary and pancreatic secretions, albumen and other principles of chyle begin to appear. This albumen is supposed, by Tiedemann and Gmelin, to be derived partly from the pancreatic fluid, which contains a large proportion of this principle; but most of it, probably, is developed from the food itself, by the changes which it undergoes in the duodenum. The albumen and the other chylous principles, are absorbed by the lacteals; and, combined together, they constitute the chyle.

According to Tiedemann and Gmelin, and some other physiologists, chyle is not formed in the duodenum; for they assert that it is impossible to extract a particle of this fluid from the contents of this intestine. If this be true, the office of the duodenum

is more completely to animalize the chyme, and to develope these principles or materials, necessary to the formation of the chyle. Leuret and Lassaigne, however, assert that all the essential principles of chyle pre-exist in the chyme. Albumen, which is the basis of the chyle, exists abundantly in the chyme of the duodenum; and particles of fibrin also, they affirm, may be detected in it. If chyme be examined with the microscope, globules may be perceived in it, which exactly resemble the globules of fibrin which exist in the chyle. These globules are not present in the gastric juice, intestinal fluid, bile, or pancreatic secretion; and, consequently, can be derived only from the food. In what manner the acidity of the chyme diminishes, as it descends in the small intestines, is not fully determined. Many physiologists suppose, that it is neutralized by the soda of the bile. Leuret and Lassaigne remark, that in chylification, the bile and the pancreatic fluid prevent the fermentation of the chyme, by neutralizing its acid principles; and that fat substances, which had not been completely converted into chyme, are dissolved by the bile, and rendered suitable for nutrition. Tiedemann and Gmelin, on the contrary, maintain that the bile is wholly incapable of dissolving fat.* They also suppose, that the soda of the bile unites with and neutralizes a part of the hydrochloric and acetic acids of the chyme; and that the free acid, still remaining in the latter, precipitates the mucus of the bile in a state of coagulation, and with this, a great part of the colouring principles of the bile; as appears from the fact, that the mucus which is precipitated is of a brown colour. Besides this mucus, several other principles are precipitated from the bile, as cholesterine, margaric acid, and resin, which Tiedemann and Gmelin found in the insoluble contents of the small intestines, and which contribute to the formation of the fæces. The German physiologists, as well as Leuret and Lassaigne, found that digestion and the formation of chyle, continued after tying the ductus choledochus; from which they inferred, in opposition to Mr. Brodie, that the bile has no agency in chylification.

According to Beaumont, bile is seldom present in the stomach; but when fat or oily food has been used for some time, this fluid passes into the stomach and mingles with the gastric liquor.

The pancreatic fluid, which contains a large quantity of albumen, a substance resembling caseine, and another, which has the property of becoming red by the action of chlorine, Tiedemann and Gmelin suppose, contributes to the assimilation of the chyme in the small intestines by the admixture of its principles, which

* La bile n'est pas capable de dissoudre le plus petit atome de graisse. Elle ne peut, donc contribuer a sa résorption que d'une manière méchanique en la tenant en suspension, quand elle est tres divisée.—*Tiedemann et Gmelin, Recherches, &c.*

contain a large quantity of azote. That these principles contribute to the assimilation of the chyme in the small intestines, appears probable from the fact that they progressively decrease, as the contents of the intestines proceed in their course, being, undoubtedly, absorbed with the assimilated part of the aliment. Thus, according to Tiedemann and Gmelin, the contents of the small intestines contain a constantly decreasing proportion of albumen, of caseous matter, and of the peculiar substance which becomes red by the action of chlorine, in their progress through this portion of the intestinal canal. The office of the pancreatic fluid in animalizing the food, the German physiologists also infer from the greater comparative size of the pancreas in animals which live on vegetables, than in such as feed on animal matter. The wild cat, which is wholly carnivorous, has a much smaller pancreas than the domestic cat, which lives partly on vegetable food, though the latter is a much smaller animal.

The uses of the intestinal fluid are various. It probably completes the solution of those parts of the aliment which were imperfectly dissolved by the gastric fluid. It also dilutes the chyme, and facilitates its progress through the intestinal canal, and lubricates the inner surface of the tube. Tiedemann and Gmelin also suppose that it serves as a medium by which the chyme is united with the bile and pancreatic fluid.

The analysis of the contents of the small intestines, furnished Tiedemann and Gmelin with the following ingredients, viz:

1. A *free acid,* the acetic, and sometimes the butyric. This is, perhaps, derived chiefly from the gastric fluid.

2. *Albumen.* This principle, as already observed, is found in considerable abundance in the duodenum, and gradually diminishes in the inferior portion of the small intestines. The albumen Prout supposed to be formed out of the chyme only, in the duodenum, by the agency of the bile and the pancreatic fluid; for he says he never observed any trace of it in the chyme, or the aliments dissolved by the gastric fluid. Tiedemann and Gmelin, however, observe, that when the food consists of liquid white of eggs, or when it contains albumen, this principle is dissolved by the gastric fluid, and passes into the duodenum with the chyme unchanged. Not only liquid white of eggs, but flesh, glue, and bread made of spelt, bones in dogs, and oats in horses, furnished an abundance of albumen; while fibrin, boiled white of eggs, gluten, milk and cheese, furnished but little. As the pancreatic fluid contains a great quantity of albumen, it is also probable that this principle, in the contents of the small intestines, is derived partly from the former. It is gradually absorbed by the lymphatics of the small intestines, and forms the basis of the chyle.

3. *Caseine.* Tiedemann and Gmelin almost always found in

the filtered fluid of the small intestines, a matter which was precipitated by distilled vinegar and the other acids, and which resembled caseine. This matter they suppose to be produced, partly by the secretion of the intestinal canal, and partly to be derived from the pancreatic fluid, which contains a matter resembling it. They suppose it to exercise an important part in the assimilation of alimentary substances, and in their conversion into animal matter by imparting azote. It is a more highly azotized principle than albumen, and is absorbed by the lacteals.

4. A matter precipitated by chloruret of tin, and composed chiefly of ozmazome and saliva. This also is absorbed.

5. A substance which becomes coloured of a rose or peach-flower red by chlorine, is almost always found in the small intestines. An excess of chlorine destroys the colour. It was found, in dogs, horses, and sheep, in the duodenum and the small intestines. Tiedemann and Gmelin suppose, that it is derived from the pancreatic fluid, in which it exists. It is never found in the stomach; but the ligature of the biliary ducts does not prevent its appearance. Consequently it is not derived from the bile. It is absorbed, and perhaps contributes to the assimilation of the food.

6. Besides the foregoing, several substances were extracted by alcohol, which were insoluble in water, as fat, stearine, the colouring principle and the resin of bile, and cholesterine.

7 and 8. Carbonate of ammonia, and alkaline carbonates, phosphates, and sulphates; with carbonate and phosphate of lime. On the whole, upon considering the changes which the food undergoes in the stomach and intestines, so far as they can be traced, it appears that its conversion into albuminous matter, which forms the basis of chyle and blood, is the great business of digestion. It is true that no albumen is developed in gastric digestion; for none can be detected in the chyme, except when the food consists of albuminous matter. But albumen is formed abundantly in the duodenum, and diminishes rapidly in the inferior parts of the small intestines, in consequence of its being absorbed by the lacteals; and Dr. Prout is of opinion that the change which the aliment undergoes in the stomach consists in an approach to the nature of albumen, though none of this principle can be discovered in the chyme of the stomach, when it has not existed in the food.

Motions of the small intestines. During digestion the peristaltic motions of the intestinal canal are performed with energy. These motions consist in alternate contractions and relaxations of the muscular fibres. The passage of the chyme through the duodenum, however, is slow; a fact which is owing to several causes, as, for instance, the deficiency of the peritoneal coat, admitting of an easier dilatation of this intestine; its greater

dimensions than those of the other small intestines; the weakness of its longitudinal fibres, and its various curvatures; and finally, the great number of its valvulæ conniventes, or transverse folds of its mucous membrane.

According to Brachet, the motions of the duodenum, like those of the stomach, depend on the influence of the pneumogastric nerves; for the section of these nerves a few hours after taking food, paralyses the duodenum and the superior part of the small intestines, in consequence of which the alimentary mass is arrested in its progress. The influence of the par vagum, however, does not extend through the whole of the small intestines; for the inferior part has been found to empty itself of alimentary matter injected into it after the section of these nerves, while the aliment injected at the same time into the superior parts, has been found partially digested in the same places. The inferior part of the small intestines appears to be under the influence of the spinal marrow, for the section of this medullary cord in the lower part of the back, arrests the progress of the chyme, suffering it to accumulate in the lower part of the small intestines, and in the large intestines. It appears then, according to Brachet, that the muscular coat of the small intestines receives the nervous influence which stimulates it from the cerebro-spinal system; and that, in respect to its power of contraction, it is under the influence of this system.

V. *Absorption.* The contents of the small intestines, consisting of a mixture of chyme, the mucus of the intestines, and the intestinal liquor, of bile and pancreatic fluid, become more and more consistent, as they advance further in the canal by the contraction of its muscular tunic. The fluid parts are imbibed by numerous lymphatic vessels, originating in its mucous membrane, and conveyed under the form of chyle, into the thoracic duct, and thence into the torrent of the venous blood near the heart. The subject of absorption will be considered hereafter. The intestinal mucus, rendered more consistent, and combined with the insoluble and indigestible parts of the food, and with the fat, the resin, the colouring matter and mucus of the bile, which form the incipient excrementitious mass, first assumes a distinct character in the last third of the small intestines. They arrive at length, by degrees, at the cæcum, where they remain some time, and where, as Tiedemann and Gmelin think, a last effort is made by nature to extract from the undissolved parts of the aliment, whatever they may contain capable of affording nourishment. Before considering further the functions of this part of the alimentary canal, it may be proper to describe the result of duodenal digestion, the nutritious fluid called chyle, though it is asserted by several physiologists that this fluid does not exist in the intestines, but that it is formed by the action of the absorbent vessels, exer-

cised upon the nutritious principles developed by the second digestion.

Chyle is the fluid contained in the lacteals. It is absorbed by these vessels from the aliment, after it has been digested in the stomach and duodenum, and is destined to the renovation of the blood. It is a fluid of a milk-white colour; but it varies in its consistence and appearance in different classes of animals, and according to the qualities of the food, and the quantity of the drinks. In carnivorous animals it is opaque; in herbivorous, transparent and of a greenish colour; in birds and fishes, thin, serous, and transparent. It is said to have a spermatic odour, and a sweetish or saltish taste, wholly unlike that of the aliments from which it is formed. Its specific gravity is superior to that of water, but less than that of blood. According to Tiedemann and Gmelin, and Magendie, it is alkaline.

In its chemical composition it has a strong analogy with blood. If left to itself, it coagulates, and separates into three parts, viz. a fluid, a coagulum, and a peculiar fatty substance. The first is an albuminous fluid, like the serum of the blood, and coagulable by fire, alcohol, and acids, contains the same salt in solution, and differs from the serum of the blood only in containing a peculiar fatty matter. The coagulum, like that of the blood, is formed of fibrin and a colouring matter. This latter substance, however, is white, instead of being red. The coagulum also contains a peculiar fatty matter not found in the blood. According to Bauer, Dumas and Prevost, chyle exhibits, under the microscope, the same globules as the blood, with the only difference that the globules are not surrounded with a coloured envelope. Leuret and Lassaigne affirm, that among all animals, whatever their food may consist of, the chyle contains fibrin, albumen, and a fat matter, muriate of soda, and phosphate of lime, in variable proportions. They also observe, that the fibrin is not in proportion to the azote contained in the food; and that the chyle of animals fed upon gum and sugar, contains as much fibrin as that of those which are nourished exclusively upon meat. The same, they affirm, is true respecting the albumen contained in the serous part of the chyle. Magendie, on the contrary, asserts that chyle formed from flesh contains more fibrin; that from sugar, comparatively little; while that which is produced from oil, contains more of the fatty matter. According to Marcet, chyle produced from vegetable aliments contains three times as much carbon as that formed out of animal substances; this last is always milky, and its coagulum opaque and rose-coloured, and covered with a layer of cream-like fluid; while vegetable chyle is destitute of this principle, is transparent, and has a colourless coagulum. Tiedemann and Gmelin affirm, that chyle does not coagulate before it has passed through the mesenteric ganglions; and are

of opinion, from this fact, that the fibrin in the chyle is not derived immediately from the food. The white colour of the chyle is attributed by some physiologists to the fatty matter present in it. Leuret and Lassaigne found the chyle milky and opaque, from the presence of this matter in the absorbents; but limpid, colourless, and destitute of fat, in the thoracic duct. In the thoracic duct in dogs, it has been observed of a reddish colour, owing, according to Tiedemann and Gmelin, to the mixture of some of the colouring matter of the blood with it. In its passage from the intestines through the absorbent system, the chyle evidently undergoes considerable changes in its sensible and other properties, and probably becomes more completely assimilated and animalized. Leuret and Lassaigne say, that it is clearer and more aqueous as it issues from the ganglions. Vauquelin observes, that it assumes a rose colour in its progress in the lymphatic system, and Tiedemann and Gmelin, Emmert and Reuss assert, that it presents, in its exit from the mesenteric glands, a redder colour, contains more fibrin, and is more coagulable, sometimes depositing a scarlet-coloured cruor; changes which are ascribed, with apparent reason, to the action of the mesenteric glands. It is said to become red by exposure to oxygen or even atmospheric air. Out of the body it putrefies in a few days, if formed out of animal food; but vegetable chyle, it is said, will resist putrefactive decomposition several weeks. The analogy of chyle with the blood, in its composition and properties, is evident, from the history of the fluid, and it may properly be considered as blood in a rudimentary state.

Functions of the Cæcum. This intestine is considered, by Tiedemann and Gmelin, as a reservoir, having some analogy with the stomach, especially in animals which feed on coarse vegetable matter, as ruminating animals, horses, the rodentes, and the pachyderms, in which this intestine has a large capacity, while in the carnivorous animals, as cats and dogs, it is small, and is entirely wanting in those animals which feed on fruits and the sweet roots of plants, as the bear and the badger. The large and numerous glands of this intestine secrete an acid fluid, which mixes with and dissolves the remains of the undigested aliment, that continues some time in the cæcum. This secretion also contains a little albumen, which is found in greatest abundance in animals which feed on vegetable matter. This albumen is supposed, by Tiedemann and Gmelin, to contribute to the assimilation of the aliments dissolved by the acid secretion. In this intestine also first appears the excrementitious matter of the intestines, under the form of a soft brownish or yellowish-brown paste, with the peculiar feculent odour, which Tiedemann and Gmelin suppose is derived from a volatile oil secreted principally by the cæcum.

Schultz's views of the functions of the cæcum, founded on experiments, are similar to those of Tiedemann and Gmelin. He maintains that there are two digestions, one of which is effected in the stomach, the other in the cæcum. The latter he supposes to be especially active in the assimilation of vegetable food. He infers from his experiments that the residue of gastric digestion, when it reaches the cæcum, becomes acid a second time in this intestine, and that this secondary acid chyme is there neutralized by bile, exactly as the gastric chyme was in the duodenum. Hence there is a twofold consumption of bile; which he says is always present in the course of the small intestines. For it is a mistake to suppose that all the bile secreted by the liver during fasting is laid up in reserve in the gall-bladder. Much the larger part flows into the intestines, during the empty state of the stomach. During fasting, however, this bile does not enter the cæcum, but collects above the cæcal valve, where it remains until the acidification of the contents of the cæcum, when the valve opens and admits it into the intestine. Schultz conceives that there is an antagonism between the gastric and cæcal digestions. For when the bile is chiefly consumed on the gastric chyme, the cæcal digestion is imperfect; and on the other hand, when the bile flows freely into the cæcum, the acidity of the chyme in the duodenum cannot be neutralized. In those animals in which this function is most perfectly developed, each digestion has its appropriate period, and no interference takes place between them. The period of action of one coincides with that of repose of the other.

These views of the functions of the cæcum, however, are not entertained by other physiologists, though it is in this intestine that a feculent character first appears in the contents of the alimentary canal.

Defecation. The passage of the fæces through the large intestines is slow, but varies, according to a variety of circumstances, from ten, twenty, or twenty-four hours, to several days. In some instances substances have remained several months in the cells of the colon. During its sojourn in the large intestines, the feculent mass becomes more consistent by the absorption of its thinner parts; its saline principles increase; the resinous and colouring matter, derived from the bile, become more concentrated, and impart a more stimulant quality to the mass. The fact that the body may be nourished and supported for a considerable time, by nutritive injections, appears to prove, not only that active absorption is exercised by the large intestines, but also, either that a sort of digestion is performed by this portion of the alimentary canal, or that the absorbent vessels of the rectum and colon, exert an assimilating power upon the crude

aliment absorbed by them. In the rectum the fæces become more dense by the absorption of their aqueous part, and assume the shape under which they are excreted.

The large intestines differ from the small in the disposition of their muscular fibres; the longitudinal ones being disposed in three bands, and shorter than the intestine, so that they pucker it up, forming numerous pouches or cells. The mucous membrane presents no trace of valvulæ conniventes, but is furnished with a great number of mucous follicles. Its nerves are derived from the hypogastric and lumbar plexuses and its arteries from the superior and inferior mesenteric. The contractions of the muscular fibres of the large intestine are wholly without the domain of the will. But in defecation, or the expulsion of the fæces from the rectum, several accessory muscles are employed, which are under the control of this power, as the diaphragm above, the ischio-coccygeal muscles, the levator ani, and the abdominal muscles. Astruc, and some others, supposed that defecation was performed exclusively by the efforts of the rectum; an error which called forth the witticism of Pitcairn—*Ast credo Astruccium nunquam cacâsse.* The concurrence of the voluntary muscles with the action of the intestine itself, is indispensable to overcome the contraction of the sphincter of the rectum, particularly in the expulsion of fæces of a hard consistence, which sometimes requires a strong effort of the will. The act is finally accomplished, principally by a contraction of the abdominal muscles upon a full and sustained inspiration, with the glottis closed, so that it is impossible to speak during the expulsive effort.

According to Berzelius, fæces afford the following ingredients, viz. water, 73.3; remains of animal and vegetable substances, 7.0; bile, 0.9; albumen, 0.9; extractive matter, 2.7; substances formed of altered bile, resin, animal matter, &c. 14; salts, 1.2. These salts are the carbonate, the muriate, and the sulphate of soda; ammoniaco-magnesian phosphate, and phosphate of lime.

The Liver.

This voluminous gland is one of the most important organs in the whole system, not only on account of its functions, but of its peculiar structure and circulation, and its sympathies with other important viscera.

It is found in all the vertebrated animals, and in the mollusca, in many of the crustacea, and the arachnides. In birds, reptiles, and fishes, its volume is greater in proportion to the size of the body, than in the human species and the mammalia. In man it is the most voluminous of the viscera, especially in the fœtal state.

It is situated in the right hypochondriac region, and the corresponding part of the epigastrium, having above it the *diaphragm*, to which it is connected by a fold of the peritoneum, called the suspensory ligament of the liver; below the right kidney, and the transverse colon and the stomach; behind the last dorsal vertebræ; and before the anterior part of the base of the chest.

Attached to the lower part of the liver, and partly imbedded in it, is a pyriform sac, called the gall-bladder, having its fundus or larger extremity placed forward, in a groove of the anterior border of the liver, and frequently projecting beyond it; and its neck and smaller extremity turned backwards and terminating in a canal, called the cystic duct. It is composed of two membranes or coats, viz. a cellular or muscular, as it is considered by some anatomists, and an interior mucous one. Besides these, it is partly covered by the peritoneum, by which it is attached, and the liver.

The colour of the liver is a reddish brown; but in a diseased state it varies a good deal, becoming darker or lighter, according to the nature of the disease. In some cases it becomes universally of a cream colour. According to Rudolphi, the very dark colour of the organ is connected with a softness of its texture and with a dark-coloured bile; and, on the other hand, an unusually light colour of its substance, with a firmer texture and a light-coloured bile. The substance of the liver is formed of a glandular parenchyma, the granulations of which become apparent by lacerating its tissue.

The importance of the liver is manifest from the immense supply of blood which it receives, and from the extraordinary distribution of its vessels. It differs from all the other glands in receiving a large supply of venous blood in addition to the arterial blood which is sent to it in common with all other parts of the body.

Its arterial blood it receives principally by a branch of the cœliac artery, called the hepatic. It also receives some branches from the coronary artery of the stomach, and the inferior diaphragmatic arteries. Sometimes a branch of the superior *mesenteric* is sent to the right lobe. Its venous blood is derived from the viscera of the abdomen; the veins of which in their course to the liver unite into a large trunk, called the *vena portæ*. On entering the liver, this great vein divides and subdivides into innumerable branches, in the manner of an artery, and is distributed to every part of the gland. The system of the vena portæ is a curious anomaly in the circulation, and was compared by Galen to a tree whose roots were dispersed throughout the abdomen, and its branches in the liver. This organ thus possesses two distinct vascular systems, an arterial and a venous,

a character in which it resembles the lungs. The extreme divisions of these two vessels, the hepatic artery and the vena portæ, terminate in the radicles of the hepatic veins, which gradually unite into large venous trunks, that enter the vena cava inferior, and convey the returning blood to the heart. From the extremities of these vessels, also, and communicating with them, spring the minute radicles of the biliary duct, called the pori biliarii, which secrete the bile from the blood; and by their union in a large trunk, constitute the hepatic duct. Haller says, that the radicles of the biliary ducts communicate immediately with the last divisions of the vena portæ, a structure from which he explains the passage of the bile into the blood in jaundice, when an obstacle in the hepatic duct prevents the passage of this fluid into the intestines.

The hepatic duct, which is formed by the union of all the excretory ducts of the liver, is a canal about the size of a writing-quill, and an inch and a half in length. It is joined at a very acute angle by the duct of the gall-bladder, called the cystic duct, and forms with it the ductus choledochus, a canal eighteen or twenty lines long, which pierces the coats of the duodenum, and terminates on the inner surface of that intestine, three or four inches from the stomach. The gall-bladder is wanting in many animals. It has been absent in man, without any apparent injury to health.*

The ductus choledochus is wanting in many of the amphibiæ, in which the hepatic and cystic ducts open separately into the duodenum. In fishes this duct arises immediately from the gall-bladder.

The nerves of the liver, which are few in number compared with its volume, are derived principally from the solar plexus, and follow the course and branchings of the hepatic artery. Some of its nerves, however, it derives from the pneumogastric. It is abundantly supplied with lymphatics; these originate in the parenchyma of the organ, and contain a yellowish-coloured lymph; the colour being derived from an admixture of bile absorbed by them.

The great office of the liver is the secretion of bile. In regard to this secretion, however, several questions have arisen which have led to much controversy among physiologists. One relates to the source of this secretion; another to the uses of it. With regard to the source of the bile, it has been a question with physiologists, whether this fluid is secreted out of venous or arterial blood; since the liver is supplied with both kinds, by the hepatic artery and the vena portæ. Some physiologists have contended, that the hepatic artery supplies the materials from

* Lepelletier.

which the bile is secreted, from the analogy of the other secretions, which are all formed from arterial blood. To this, however, it is replied, that carbon is secreted in the lungs from the venous blood of the pulmonary artery, which ramifies through the lungs as the vena portæ branches in the liver; and therefore that it is possible that bile, which contains a large proportion of carbon, may also be secreted from venous blood. Comparative physiology also furnishes a reply to this argument, in the fact, that in some of the lower animals, as the reptiles, the urine is secreted in a great measure out of venous blood. Another argument is founded on the disproportion between the vast quantity of venous blood which the liver receives, and the inconsiderable quantity of bile secreted by the organ. A disproportion, however, quite as great if not greater, exists between the vena portæ and the hepatic veins, which must nevertheless convey, not only the residual blood of the vena portæ, but that of the hepatic artery also, into the vena cava inferior. Besides, it is probable, and indeed certain, that a part of the bile secreted is immediately absorbed by the lymphatics, and conveyed into the thoracic duct.

Mr. Abernethy describes a remarkable case, in which the vena portæ opened directly into the inferior vena cava. The hepatic artery was larger than usual. In this case the bile found in the biliary ducts must have been secreted from the blood of the hepatic artery. Lawrence describes a case in which a similar anomaly existed. To this it may be added, that the vena portæ does not exist in the invertebrated animals; and yet these possess a liver, which secretes bile.

Injections pass from the hepatic artery into the biliary ducts, proving a direct anastomosis of the ultimate branches of the hepatic artery with the radicles of the biliary ducts.

Tying the hepatic artery is said to cause a cessation of the secretion of bile. This, however, is inconclusive, because the liver is nourished by the arterial blood of this vessel; and if its nourishment is withheld from it, and the stimulus of arterial blood withdrawn, it is not surprising that its secretory functions should be suspended. The fact, however, is denied, and needs confirmation. That the bile is secreted from the portal blood, is inferred, on the other hand, from the following considerations, viz:

The vena portæ conveys a much larger quantity of blood into the liver, than the hepatic veins can carry out. The excess, it is reasonable to suppose, is employed in the formation of bile. If it be not so disposed of, it is difficult to imagine what becomes of it.

Injections pass very easily from the vena portæ into the biliary ducts. It is alleged, also, that the venous blood is more analogous

to bile, in its constitution and properties, than arterial, as it contains more carbon and hydrogen, principles which abound in bile, but less azote; and is darker coloured and more consistent. The peculiar properties of the blood of the vena portæ, may also be considered as favourable to this opinion. It appears, from the researches of Schultz, that the portal blood differs in its constitution, in several respects, from that of the arteries and other veins. It is blacker than other venous blood; and it is not reddened by the neutral salts, by atmospheric air, nor even by the action of oxygen gas. It does generally coagulate, and in those cases in which coagulation takes place, it becomes liquid again, either partially or wholly, at the end of from twelve to twenty-four hours. It contains less fibrin than the arterial and ordinary venous blood, as might have been inferred from its inferior coagulability, but almost twice as much fat. Some physiologists have recognised in these peculiarities an approximation to the qualities of the bile.

Tying the vena portæ occasions a suspension of the secretion of bile.

According to Rudolphi, there is a free communication between all the blood-vessels of the liver, viz. the branches of the hepatic artery, those of the vena portæ, and of the hepatic veins, and the biliary ducts; from which he infers, that the principles out of which the bile is formed are easily separated from the blood. He affirms, that he has seen coloured water injected into the vena portæ readily pass into the hepatic artery. Perhaps this free communication is an argument in favour of bile being secreted from both kinds of blood.

The excretory duct of the liver terminates in the duodenum, three or four inches from the pylorus. But before it arrives at this intestine, it is joined by the duct of the vesicula fellis. Of course, at this point, the bile from the liver can pass in one of two directions, viz. either directly into the duodenum, or by turning a very acute angle, into the gall-bladder. During digestion in the duodenum, when this intestine is stimulated by the presence of chyme, and is in a state of vital erection, the stimulus is communicated to the mouth of the common duct, and propagated along both its branches, to the liver and gall-bladder; so that the hepatic and cystic bile are solicited, at the same time, to pass into the duodenum; and the gall-bladder and the hepatic duct both empty themselves of bile. But when the duodenum is not engaged in the work of digestion, the hepatic bile is diverted into the other channel, and passes into the gall-bladder, where it remains until called for, and undergoes some change in its properties, becoming more concentrated, bitter, and viscid, in consequence of the absorption of its aqueous parts by the lymphatics; and probably, receiving some addition from the secretion of the

mucous membrane of the gall-bladder. If it be retained a long time in the vesicula fellis, its bitterness becomes excessive, and its colour of a deep green, by the great concentration of its peculiar principles.

Bile differs more from the blood than most of the other secreted fluids. It is a fluid of a greenish brown colour, extremely bitter and viscid. It consists of water, albumen, resin, and soda, both free and united with the phosphoric, sulphuric, and hydrochloric acids, and a yellow colouring matter. It derives its leading properties from a colouring fatty substance, called cholesterine, which forms the basis of biliary concretions; picromel, a resin which gives the bile its bitterness; albumen, which causes it to froth on being agitated; free soda, to which it owes its alkaline properties; and various salts, composed chiefly of soda, combined with phosphoric, sulphuric, and hydrochloric acids.

The secretion of bile appears to be unintermitting. It has been found in experiments, in which the orifice of the common duct was laid bare, that the bile issued drop by drop, and gradually diffused itself over the intestine.

The lymphatics of the liver contain a lymph coloured with bile, which they convey into the thoracic duct. Berthold supposes that the bile contained in this lymph, contributes to the assimilation of the chyle.

The uses of the bile have already been considered in part. It probably acts as a stimulant to the mucous and the muscular coats of the intestines, soliciting a flow of the intestinal fluids, and exciting the peristaltic contraction of the canal. Hence the unusual dryness of the fæces, and the constipation of the bowels in jaundice, and in animals in which the biliary duct has been tied. Tiedemann and Gmelin also suppose that it contributes to animalize those articles of food which do not contain azote, by imparting to them its own principles, which are highly charged with azote; that it neutralizes a part of the acid contained in the chyme, which is derived from the gastric fluid; and that it counteracts the putrefaction of the contents of the intestines, which they infer from the fact that the fæces are unusually fœtid in dogs in which the ductus choledochus has been tied.

But the German physiologists also view the bile as an important excretion, designed to maintain the blood in a state of composition necessary to qualify it for the nutrition, in the different organs. The reasons on which this opinion rests are briefly the following, viz.

1. Most of the constituent principles of the bile, as the resin, the colouring matter, the mucus, and the salts, concur to the formation of the fæces, and are rejected from the system with the latter.

2. When the bile by any cause is prevented from passing into

the intestinal canal, as in animals in which the biliary duct has been tied, or in persons affected with jaundice, the materials of the bile are separated from the blood by means of other secretory organs, particularly by the kidneys, but partly by the serous and mucous membranes, and by the skin. The principles of this fluid are also deposited in the cellular tissue, in the coats of the arteries, veins and lymphatics, and even in the dense fibrous tissues, the cartilages and bones, which all assume a yellow hue.

3. The liver appears to perform a function analogous to that of the lungs; since it separates from the venous blood a large quantity of carbon, in the form of resin, colouring matter, fatty matter, and mucus. In the lungs the excess of carbon, derived from the vegetable part of the food, is excreted in the form of a gas, and in a state of oxidation; but in the liver it is thrown off in the form of a liquid, and in combination with hydrogen, constituting the resin and fatty matter of the bile, and still in a combustible state. A fact favourable to the opinion that the liver is auxiliary to the lungs in decarbonizing the blood, is that the resin of the bile, which exists so largely in this fluid, and is excreted from the body with the fæces, exists in the greatest proportion in herbivorous animals. Thus the bile of the ox contains much more of it than human bile, or that of the dog; and Tiedemann and Gmelin infer that this resin is derived chiefly from vegetable aliment. These physiologists also remark that the lungs and liver, in different species of animals, are in a state of antagonism to each other. If the lungs are largely developed, if the system frees itself of a large quantity of oxidated combustible matter, by the respiratory organs, the liver is small, and the secretion of bile inconsiderable. But if the lungs are small, or imperfectly developed, the liver is large, and the biliary secretion copious. Thus the liver is proportionally large in reptiles which respire by means of lungs with large cells, like sacs or bladders, and whose pulmonary circulation is incomplete, and which decarbonizes the blood slowly. On the other hand, warm-blooded animals with well-developed lungs, as the mammalia and birds, which consume the largest proportion of oxygen in a given time, and throw off the greatest quantity of carbonic acid, have the smallest livers in proportion to the size of their bodies. In fishes, on the contrary, which live in the water, and breathe by means of gills, the liver is comparatively large. In these animals respiration is very imperfect, being maintained only by the small quantity of air combined with the water in which they live, and being performed by gills, the structure of which is less favourable than that of the lungs to the absorption of oxygen. The enormous size of the liver in the mollusca, which breathe by gills or by small, imperfectly developed lungs, tends to corroborate the same opinion. It is also worthy of remark, that the system

of the vena portæ is more highly developed, and much more complicated in its structure in reptiles and fishes, than in the mammalia and birds. For while this great venous trunk in the latter is formed only by the veins of the stomach and intestinal canal, the spleen and pancreas, in reptiles and fishes it receives several other veins. Thus in tortoises, not only the veins of the spleen and of the intestinal canal, but those of the posterior extremities, of the pelvis, of the tail, and even the azygos, unite with the vena portæ. In serpents, this vein also receives the right renal vein, and the intercostals. In fishes, the vena portæ receives the veins of the tail, of the kidneys, and of the genital organs; so that the quantity of venous blood which arrives at the liver is proportionally much greater than in the other classes; and indeed the greater part of the venous blood traverses the liver and contributes to the secretion of the bile, before it arrives at the heart and the organs of respiration.

4. The great comparative size of the fœtal liver furnishes another argument in favour of the view that the bile is an excrementitious fluid. During the fœtal state, the greater part of the blood which is brought from the placenta by the umbilical vein arrives at the system of the vena portæ, and circulates in the liver before it is conveyed to the heart by the inferior vena cava. The bile also is secreted abundantly, as appears from the great quantity of meconium which exists in the intestines in the later period of utero-gestation. It is evident, that in the fœtus the bile cannot be subservient to chylification; and the probability is, that the office of the liver in this stage of existence is to purify the blood of the umbilical vein from such organic principles as are injurious to the animal economy, and to maintain the composition of the blood in a state suitable for the nutrition of the body. It is probable, therefore, that in the fœtal state the liver acts in part as a substitute for the lungs, which, after birth, perform the office of purifying the blood of noxious principles, by a kind of combustion with the oxygen of the air.

5. Another fact which is relevant to the subject is, that the secretion of bile continues in the hybernating mammalia, the reptiles, and the mollusca, although these animals take no nourishment during the whole course of their winter sleep.

6. Tiedemann and Gmelin also adduce some pathological facts to corroborate their opinion. In general, they remark, the secretion of bile is augmented in derangements of respiration; and whenever an air is respired which is vitiated by putrid animal or vegetable emanations.

The Pancreas.

This is a gland five or six inches in length, of a whitish colour, and lying transversely across the body of the twelfth dorsal ver-

tebra, covered by the stomach, and almost circumscribed by the three curvatures of the duodenum. It receives numerous blood-vessels from the splenic, the right gastro-epiploic, the superior mesenteric, the coronary of the stomach, the hepatic and the inferior diaphragmatic. It derives its nerves from the ganglionic system, by the hepatic, the superior mesenteric, and the splenic plexuses.

This gland is of a granulated texture, consisting of small granules, or acini, united together by cellular membrane; these acini being aggregated into smaller, and these again into larger lobes. These lobes give origin to the fine pancreatic ducts, which unite together into one large excretory, called the duct of Wirsungius. This canal runs the whole length of the pancreas, and opens, by its larger extremity, into the duodenum, near the end of its second curvature, sometimes by a separate orifice, and sometimes by a common mouth, with the ductus choledochus. In some cases its mouth has been found two inches distant from the orifice of this duct. Its passage through the coats of the intestine is oblique, running under the mucous membrane in such a manner as to leave a free border of the latter, which exercises the functions of a valve. Sometimes there are two pancreatic ducts.

This gland is found in all the mammalia, in birds, and in the amphibia. It exists in some fishes, but in others it is wanting.

The pancreatic fluid is a white, or light yellowish, somewhat viscid fluid, inodorous and semi-transparent, and of a slightly saline taste. It becomes frothy by agitation, and coagulates by heat; and when it is putrefying diffuses an ammoniacal odour. Physiologists have differed a good deal as to its constitution and properties. Some consider it as an acid, others as an alkaline fluid. Leuret and Lassaigne, and many other physiologists, consider it as very similar to saliva; while Tiedemann and Gmelin say that it differs essentially from saliva, in containing a free acid, a large proportion of albumen and caseine, of which the saliva offers only slight traces; and in the absence of mucus, of salivary matter, and of the sulphocyanate of potash.

The secretion of this fluid appears to be slow. Magendie exposed the orifice of the pancreatic duct in dogs, and wiped the mucous membrane of the intestine dry with a piece of fine linen; and he observed that the pancreatic fluid issued only in drops, which scarcely appeared once in half an hour, and sometimes not so often. In birds the quantity which issues is much greater. Leuret and Lassaigne obtained from the pancreatic duct of a horse, in half an hour, three ounces of fluid. Tiedemann and Gmelin obtained from a large dog only about ten grammes, or one-third of an ounce, in four hours. A drop issued out every six or seven seconds. When the animal made a deep inspira-

tion, and the abdominal viscera were strongly compressed by the diaphragm, the discharge was more copious, sometimes several drops issuing in a second. Schuyl obtained two ounces in about three hours. It appears from these experiments that the quantity of this secretion varies much at different times, and probably under different circumstances. The stimulus of chyme in the duodenum, propagated from the mouth of the duct to the interior of the gland, gives rise to an increased flow of blood to it, and a more copious secretion of the pancreatic fluid. From the position of the gland, in relation to the stomach, it must be exposed to pressure whenever this organ is distended with food, and probably is stimulated by the pressure to increased secretion. This gland, as before remarked, is proportionally larger in herbivorous than carnivorous animals; a fact which seems to indicate its importance in the assimilation of aliment of difficult digestion. It appears, however, that the pancreas may be extirpated in dogs without fatal consequences, or even serious injury to health. Brunner extirpated the gland in several dogs, and observed a voracious appetite and the most obstinate constipation as the consequences.

Food.

The food of man is derived both from the animal and the vegetable kingdoms. Prout remarks, that organized beings adopt as aliments, substances lower than themselves in the scale of organization. Thus, plants and the lowest kinds of animals have the power of assimilating inorganic substances, such as water and carbonic acid. In ascending the zoological scale, we find that animals generally prey upon those which are inferior to themselves in organization, in magnitude, or intelligence, until we arrive at man himself. "By this beautiful arrangement in the mode of their nutrition," Prout remarks, "animals are exonerated from the toil of the initial assimilation of the materials composing their frame; as in their food, the elements are already in the order which is adapted for their purpose. Hence, the assimilating organs do not require that complication which otherwise they would have needed, and much elaborate organization is saved."

Animal food is more easily and speedily digested than vegetable, because it approaches much more nearly to the nature of the system it is destined to nourish. Probably every kind of animal matter is capable of being converted into nutriment. Food is derived from every department of animated nature, to supply the wants, or to gratify the appetite of man. The mammiferous quadrupeds, birds, fishes, reptiles, insects, and the crus-

taceous and molluscous animals, are all greedily sought after and devoured by man.

Fibrin. Of the animal principles, those which contain the greatest proportion of azote are, perhaps, the most nutritious, as well as most stimulating. This is particularly true of fibrin, which forms the basis of muscular flesh, and is a constituent principle of the blood. It contains about twenty per cent. of azote, and is highly nutritious. The same is probably true of cheese, which the experiments of Sir A. Cooper would lead us to conclude is a substance of easy digestion, and is highly nutritious. It is highly azotized, containing about twenty-one per cent. of azote. Londe remarks, that of all aliments, the fibrinous are those which remain the longest in the alimentary canal, which exact the greatest labour of digestion, excite the greatest animal heat in the stomach, stimulate the blood-vessels of the mucous membrane, and the general circulation, and cause the most copious secretion of the gastric and intestinal fluids. It is one of those which undergo the greatest alteration by digestion, and leave the smallest residue. When fibrinous aliment contains ozmazome, it is of all kinds of food, the most exciting, and the most nutritious.

Albumen is another animal principle which is extremely nutritious, and of easy digestion. According to Tiedemann and Gmelin, the liquid white of eggs is dissolved by the gastric liquor, and passes into the duodenum without undergoing any sensible change. It is coagulated, however, by the gastric fluid before it is dissolved. Albumen exists in the blood, in the matter of the brain and nerves, and in other forms of animal matter. Caseine appears to be a modification of albumen; and the white of eggs consists of this principle. It contains about fifteen per cent. of azote. Albumen, if uncoagulated, is rapidly digested, and excites but little heat. Aliments containing it pass out of the stomach so much the more speedily, as they have been less altered by cookery. It is very nutritious, and leaves but little residue.

Gelatin is a highly nutritious principle. It is extracted from the tendinous, and ligamentous, and cartilaginous parts of animals; and constitutes the basis of soups. It is found in none of the animal fluids. The flesh of young animals contains more gelatin but less fibrin than that of old ones. Gelatin excites so little the local action of the stomach, that, according to Londe, it requires the aid of stimulants in order to be digested. It passes rapidly through the alimentary canal, and, by some authors, is considered as laxative. It produces little or no excitation of animal heat, or of the circulation, and leaves little residue.

Osmazome, according to Orfila, is stimulating, but possesses no nutritious properties.

Animal fat and oils. These principles are very nutritious, and are wholly convertible into chyme; but if separated from other animal principles, are not very digestible. But, as they exist interspersed between the fibrinous parts of animals, they render the latter more tender and easy of digestion. Even the substance of the *bones* cannot resist the powers of digestion. The spongy bones are more easily digestible than the hard; but they all contain gelatin, and many of them oil or marrow; both of which are very nutritious. The vegetable principles which afford nourishment by being converted into chyme, are starch, mucilage, sugar, oil and fats, and gluten.

Starch is found in a variety of vegetables, particularly in several of the nutritious grains, as wheat, oats, barley, rye; and it constitutes most of the nutritious parts of rice, barley, and maize; it exists also largely in potatoes. Sago, tapioca, salep, and arrow-root, consist almost wholly of starch. It is a curious fact, that as soon as starch is dissolved by the gastric fluid, it loses the property of assuming a blue colour by the action of iodine. Londe asserts, that aliments in which starch predominates, pass more speedily through the stomach than those in which fibrin, albumen, or gelatin abounds. The digestion of the amylaceous aliments produces but little elevation of heat, and no sensible acceleration of the pulse. Of all vegetable aliments they are the most nutritious.

Mucilage abounds in many of the garden plants, as carrots, beets, turnips, cabbages, lettuce, melons, &c., combined in some of them with sugar, &c., and with woody fibre. The various gums, as for example, gum arabic, consist of some modification of mucilage in a solid form. Wherever it exists it is nutritious. Mucilaginous aliments excite little or no heat, or increased activity of the circulation; on the contrary, they produce a general relaxation of the tissues, and diminish the energy of all the functions. Gum is extensively used as an aliment by the Moors of Lybia and Senegal.

Sugar abounds in the saccharine fruits, as grapes, raisins, figs, dates, the sugar-cane; pears, apples, peaches, berries, &c. In these last, it is combined with the malic acid. It also exists largely in the beet, the parsnip, the sap of the maple and of the ash. It is very nutritious; but according to Magendie, though it is easily digested, and leaves no residue, it is incapable of furnishing a chyle which can support life more than thirty or forty days. From the experiments of Magendie, it appears that an exclusive use of sugar produces ulcerations of the cornea.

Oil exists in the cocoa, chocolate, olives, almonds, and other nuts. It is very nutritious, being wholly convertible into chyme; but it is not very easy of digestion.

But the most nutritious of the vegetable principles is *gluten.* This differs from the other proximate elements of vegetable

matter, in approaching pretty nearly to the constitution of animal matter, especially in containing a considerable proportion of azote. It is the most highly animalized of vegetable principles. It exists in the farinaceous grains, particularly in wheat, in which it is very abundant; and on the presence of this principle depends the property in wheat of undergoing the *panary* fermentation, or of making bread. Wheat flour makes the best bread, from its containing more of this principle than any other grain. Substances destitute of gluten, as rice, maize, barley, are incapable of the panary fermentation, and of making good bread. It is highly nutritious.

Gluten is found, though sparingly, in various parts of the vegetable kingdom; as in certain flowers, fruits, the leaves of certain plants, cabbages, and some roots. Combined with starch, it is extremely nutritious.

Dr. Prout has reduced the various nutritious principles of animal and vegetable matter under three general heads, viz. the *saccharine*, the *oleaginous*, and the *albuminous*. The first, or the *saccharine*, comprehends *sugar*, *starch*, *gums*, *acetic acid*, and some other analogous principles; the second, or the *oleaginous*, *oils*, *fats*, *alcohol*, &c.; the third, or the *albuminous*, other animal substances, particularly *albumen*, *fibrin*, and *gelatin;* and the vegetable principle, *gluten*.*

The *saccharine group* embraces two classes of substances, viz. the crystallizable and the uncrystallizable. The crystallizable are sugar and the acetic acid. Sugar is a triple compound of hydrogen, oxygen, and carbon. But it is worthy of remark that the hydrogen and oxygen are combined exactly in the proportion in which they form water; from which it is inferred, that sugar is a compound of water and carbon, or is a *hydrate* of carbon. Vinegar is another proximate principle which is crystallizable; and like sugar is formed of carbon and water, though the proportions of the carbon and water are different from those that form sugar. They differ, however, in the circumstance, that we can form vinegar artificially, but not sugar.

The uncrystallizable substances belonging to the saccharine group are starch, and *lignin* or woody fibre. The former of these, or starch, in its composition, very nearly coincides with sugar; i. e. it is composed of water and carbon, and the proportions in which they are combined are very nearly the same as in sugar.

The second, or *lignin*, in all its varieties has been found to possess very nearly the same essential composition. It is a hydrate of carbon, consisting of equal weights of this principle and water. The affinity of these four substances appears not

* Prout.

only from their similarity of composition, but from the fact that they are convertible into one another. Thus, both starch and wood may by artificial processes be converted either into sugar or into vinegar: wood may also be converted into a kind of starch; and sugar into vinegar; though we cannot reverse the process, and convert vinegar into sugar, or starch into wood.

The *oily group* in all their varieties are all essentially the same in their composition, being composed of olefiant gas and water. Alcohol is referred to the same group by Prout, as its composition is the same.

The *albuminous group* comprehends albumen, gelatin, and fibrin, of which the animal tissues are chiefly composed, and caseine, or the curd of milk. The vegetable principle, gluten, is referred by Prout to the same class. All of the albuminous group differ from the saccharine and the oleaginous, in containing a fourth principle, viz. azote. One of them, viz. gelatin, is easily convertible into a kind of sugar.

"Such," says Prout, "are the three great staminal principles from which all organized beings are essentially constituted,"—"and, as all the more perfect organized beings feed on other organized beings, their food must necessarily consist of one or more of the above three staminal principles. Hence, it not only follows, as before observed, that in the more perfect animals, all the antecedent labour of preparing these compounds *de novo*, is avoided; but that a diet, to be complete, must contain more or less of all the three staminal principles. Such at least must be the diet of the higher classes of animals, and especially of man."

This view of the nature of aliments, Prout remarks further, is illustrated and confirmed by the composition of milk; the only substance expressly designed and prepared by nature as food; and in which, therefore, we should expect to find the model and prototype of nutritious matter in general. Now, every sort of milk, Prout remarks, is a mixture of the three staminal principles above described; for milk always contains a *saccharine;* a *butyraceous*, or *oily;* and a *caseous*, or *albuminous* principle.

These views of Prout receive some confirmation from certain experiments of Magendie, on the effects of particular kinds of diet on animals. A dog was fed exclusively upon white sugar and water, and for seven or eight days he appeared to thrive upon this diet. In the second week he began to lose flesh, though his appetite continued good. In the third he lost his spirits, and his appetite failed; and an ulcer formed on the middle of each cornea, which penetrated into the chamber of the eye, and the humours of the eye escaped. The dog died at the thirty-second day of the experiment. Similar results ensued with dogs fed on

olive oil and distilled water, except that ulceration of the cornea did not take place. Another dog, fed upon white bread, made of pure wheat, and with water, died at the expiration of fifty days. An ass fed upon boiled rice, lost his appetite, and died in fifteen days.

According to Raspail, digestion requires the presence of at least two alimentary principles in the food, viz. a saccharine or saccharifiable; and albumen or gluten. Each of these substances is indigestible by itself, because it requires the influence of one of the other class to excite the digestive fermentation. This is the true ground of the fact established by Magendie, that animals cannot be sustained on a single alimentary principle. Bread contains an abundance of both principles, viz. sugar or saccharifiable starch, and gluten. Hence its highly nutritious qualities. Flesh also contains sugar united with its albuminous tissues. Hay, which is the bread of graminivorous animals, is rich in sugar and gluten. The sugar cane is the type of this class, the other graminaceæ being diminutives of the former.

On the whole, it appears to be established by experiment, that a certain variety in the food is necessary to the health of man, and of other animals. The experiments of Dr. Stark upon the effects of various simple kinds of food, when used exclusively for a considerable time, appear to prove, that the system is reduced to a state of great debility and emaciation by such a course of diet; and that there is not a single article of food, however nutritious, capable, of itself, of supporting the vigour of the system.

The Spleen.

The spleen is a spongy vascular organ, of a flattened oblong shape, and of a livid colour, situated in the left hypochondriac region, below the diaphragm, behind the descending colon, and directly over the left kidney, adhering to the fundus of the stomach. It is supplied with blood by the splenic artery, one of the three branches of the cœliac, a large and tortuous vessel, which, before it enters the spleen, divides into several branches, from which five or six very short branches are detached to the stomach, and distributed upon its large extremity. The spleen derives its nerves from the cœliac plexus. It is attached loosely to the neighbouring parts by folds of the peritoneum and by vessels, and to the stomach especially by the *vasa brevia.*

The texture of this organ is extremely spongy, brittle, and vascular. It contains a large quantity of blood, apparently extravasated in numerous membranous cells, of which the organ seems to be chiefly composed. But according to some anatomists, on the most careful examination, no cells containing blood can be found interposed between the arteries and veins. Others on the

contrary assert, that the organ is chiefly composed of an infinite number of little cells which communicate freely with one another, and with the splenic veins. The primary branches of the splenic vein, when examined on their internal surface, appear to be perforated with a great number of orifices, through which a stylet may be passed directly into the cells of which the parenchyma of the organ is composed. At a greater distance from the trunk, the orifices, with which the coats of these vessels are perforated, become larger; and ultimately the parietes of the latter lose their continuity and separate into filaments, which become confounded with the walls of the cells before mentioned. The splenic artery almost immediately after entering the organ diminishes rapidly in volume, subdividing into minute branches, which, according to some anatomists, disappear on the parietes of the cells. These branches divide into extremely delicate vessels, which are disposed like the hairs of a pencil, but do not inosculate with one another; while the veins anastomose freely together. Injections readily pass from the arteries to the veins. Besides its blood-vessels, the spleen contains a great number of lymphatics. In addition to these constituent parts, anatomists describe a multitude of soft grayish white nodules or granulations, of about one-sixth of a line in diameter, dispersed through the substance of the spleen, the nature and uses of which are unknown. They are said to become very tumid in animals immediately after drinking.

The position and volume of the spleen are much influenced by the state of the neighbouring parts. The motions of the diaphragm in respiration are constantly changing its place; and it is also much affected by the state of the stomach. When this organ is distended by food or gas, the spleen almost comes into contact with its great extremity, and assumes a very oblique position. But when the stomach is empty, the spleen is more distant from it, and its position is nearly vertical. The volume of the spleen is lessened when the stomach is full, but augmented when that organ is empty; a fact which is accounted for by the diminished influx of blood into the spleen in the one case, and the increased, in the other. The volume of this organ is liable to be affected by several causes. It is said to be smaller in those who perish suddenly, and larger in such as die a lingering death. It frequently becomes much enlarged by repeated attacks of intermittent fever; and it is said to have been found ruptured from excessive distention, in persons who have died in the cold stage of that disease.

Its office is unknown. Many physiologists have conjectured that it is subservient, in some mode or other, to the formation of bile, an opinion which derives some probability from the fact that the splenic vein contributes to the formation of the vena portæ. Whatever may be the functions of the spleen, however, it

appears that it is not necessary to life; for animals which have been deprived of it, have not been found to suffer any inconvenience from its loss. In some instances they have even become fatter. It is said that this organ is almost invariably absent in acephalous fœtuses.

CHAPTER XVII.

ABSORPTION.

After the chyme has been subjected to the second digestion in the duodenum, its nutritious parts are absorbed and carried into the circulation, and, almost immediately afterwards, are subjected to respiration in the lungs, where their conversion into blood is completed. The route which the chyle takes in its passage from the intestines to the circulation, is through a part of the absorbent system; and the functions of this system, or the physiology of absorption, is next to be considered.

The absorbent system consists of the *lymphatic vessels*, the *conglobate glands*, and the *thoracic duct*.

The lymphatics are fine pellucid vessels, which exist in all parts of the body, and terminate in the venous system, into which they convey the fluids which they absorb. The lymphatics consist of two coats, of which the external is cellular, and capable of considerable extension; while the internal, like the inner coat of the blood-vessels, is smooth, and possessed of little extensibility, and forms numerous folds or valves, which, in general, are arranged in pairs. These valves are disposed in such a manner, with their bases directed towards the origins of the vessels, and their free margins towards the heart, as to permit the free passage of their contents toward the veins, but to prevent it in the opposite direction.

The lymphatics are endued with considerable irritability, which continues several hours after death. If an animal be killed about the close of the process of digestion, upon opening the abdomen the lacteals will be found turgid with chyle. But these vessels, irritated by the contact of the air, gradually contract; and, in the course of a minute or two, wholly disappear. A similar result may be obtained within the space of twenty hours after death. But, after this time, the irritability of these vessels is annihilated, and they continue distended with chyle, notwithstanding the contact of the air. If the thoracic duct, or any other lymphatic trunk, be tied in a living animal, and a puncture be made in the vessel below the ligature, the lymph spirts out in a

jet; but if the experiment be performed some time after death, the fluid escapes from the vessel slowly.

The lymphatics are very elastic and possessed of great powers of resistance. A lymphatic which is so fine as to be scarcely perceptible when empty, may acquire a diameter of half a line when distended by an injection; and, if again emptied, it will resume its original dimensions. Their powers of resistance are much superior to those of blood-vessels of the same diameter.

The lymphatics originate in two sources, viz. the surfaces of all the membranes, and the parenchyma, or internal tissue of all the organs. Thus, they originate, 1. From the areola of the cellular tissue, throughout its whole extent. 2. From the serous membranes, as the peritoneum, the pleura, the pericardium, the cavities of the joints, and, perhaps, those of the brain. 3. From all the mucous membranes, as the inner surface of the organs of respiration and digestion, and of the sexual and urinary organs. To this branch of the lymphatic system, the lacteals may be referred, as they spring from the mucous membrane of the digestive canal. 4. From the outer skin. They originate also, from the tissues of all the organs themselves, as the muscles, the glands, bones, &c. Hence, it appears that all parts of the organism, with the exception of the hair, the nails, the epidermis, and the enamel of the teeth, are furnished with these vessels. They have not been detected, however, it is said, in the brain, the spinal marrow, the eye, and the internal ear; though, according to Rudolphi, Mascagni and Schreger saw lymphatics in some parts of the eye; and Fohman detected them in the cornea, conjunctiva, serous membranes, inner coats of the vessels, and in the placenta and umbilical cord. Rudolphi even affirms that they have often been seen in the brain. It is a disputed point among physiologists, whether the absorbent vessels originate by open mouths or not. Some suppose that they commence in small spongy masses; others, that they originate in erectile ampullæ; others, in vesicles susceptible of transudation. But Bichat and some others think that they commence by small absorbing mouths, like those of the *puncta lachrymalia*.

In the limbs, the lymphatics form two sets, viz. a superficial, and a deep-seated. The former is situated in the cellular tissue, beneath the skin, and accompanies the subcutaneous veins; the latter is found principally, in the intermuscular spaces, round the nerves, and the great vessels. Both sets ascend from their origins towards the upper parts of the limbs, gradually diminishing in number, but increasing in volume, and at length, enter the lymphatic ganglions of the groin and axilla. In general, several absorbent vessels enter every conglobate gland, on the side remote from the heart, and a smaller number issue from it in the direction towards this organ.

In the trunk, also, the lymphatic vessels are distributed in two sets, one superficial, or subcutaneous; the other, situated on the internal surface of the walls of the great cavities.

In the thoracic and abdominal viscera likewise, these vessels form two orders, an external and internal; the former occupying the surface of these organs, the latter apparently originating in their parenchyma.

The absorbent vessels of the small intestines, and of the mesentery, are termed *lacteals.* They originate by imperceptible orifices, at the surface of the villi of the mucous coat of the small intestines, and pass between the two laminæ of the mesentery, to a double series of small ganglions, called mesenteric glands. From these ganglions arise numerous vessels, of the same nature as the lacteals, which unite into larger trunks, and these terminate eventually in the thoracic duct. Some physiologists are of opinion, that the lacteals do not terminate exclusively in the thoracic duct. According to Cowper, and Tiedemann and Gmelin, there are numerous anastomoses between the chyliferous vessels and the meseraic veins. Meckel, Lobstein, and others, have observed similar communications with the vena portæ; and other physiologists have asserted their existence in various other parts. The chyliferous vessels which issue from the mesenteric ganglions, sometimes anastomose with the radicles of the mesenteric veins. This alleged direct communication between the lacteals and the veins, has an important relation to the physiology of absorption, as will appear hereafter.

The conglobate glands, or lymphatic ganglions, are small flattened bodies, of an oval or circular shape, of different sizes, varying in diameter from the one-twentieth of an inch to an inch. They are extremely vascular, are supplied with nervous filaments, and receive lymphatic vessels, which subdivide in their substance, forming inextricable plexuses, interwoven with innumerable blood-vessels. The lymphatics which enter them are termed *vasa inferentia;* those which issue from them, in the direction towards the heart, are called *vasa efferentia.* If mercury be injected into the vasa inferentia it is observed to fill a series of cells in the gland, and afterwards escapes by the vasa efferentia. If a lymphatic gland be injected with wax, the whole substance of the gland assumes the appearance of a mass of convoluted absorbents, irregularly dilated, and which reciprocally communicate.*

The lymphatic glands are not numerous in the extremities, but are found in abundance in the thorax and abdomen. They generally exist in places where there is an accumulation of fat, as in the folds of the great articulations, in the anterior part of the ver-

* Mayo.

tebral column, and in the places where the blood-vessels penetrate the viscera. Their number is very considerable, amounting, as has been computed, to six or seven hundred; but it appears to diminish in old age.

Two or three small absorbent glands are found at the inner ankle, four or five in the ham, and from eight to twelve in the groin. These last receive absorbents from the leg and thigh, from the pudenda, the parietes of the abdomen, the nates, and the loins. Several, also, are found in the lateral parts of the cavity of the pelvis, and about the internal iliac vessels; others, on the outside of the pelvis, in the course of the glutæal and ischiatic arteries; and several minute glands are situated upon the bladder, the uterus, and the vesiculæ seminales. Numerous lymphatic glands are situated in the course of the external iliac vessels, forming a chain which extends from the crural arch to the inferior part of the vertebral column. Others are found in the hollow of the sacrum, between the laminæ of the mesorectum. Large and numerous lymphatic glands occur, also, in the lumbar region, surrounding the aorta, and the inferior vena cava. They are found, also, upon the crura of the diaphragm, over the renal arteries, round the vena portæ, and along the splenic artery. The mesenteric glands which receive the lacteals, are numerous, amounting sometimes to a hundred or more. They lie between the two laminæ of the mesentery, and are of considerable size. Opposite to the second lumbar vertebra, the absorbents of the mesentery, after passing through the mesenteric glands, unite into an oval sac, termed the *receptaculum chyli.* This reservoir, which receives also the absorbents of the lower extremities, is the commencement of the *thoracic duct,* a tortuous canal, about the size of a goosequill, which ascends between the aorta and the right crus of the diaphragm, into the posterior cavity of the mediastinum. It then ascends behind the arch of the aorta, as high as the seventh cervical vertebra, and then arches downwards, and opens into the left subclavian vein at the angle where this vessel joins the internal jugular. Its embouchure is provided with a valve, derived from the internal membrane of the vein. The thoracic duct, in its course to the subclavian vein, is joined by absorbents from the viscera and the neighbouring parts. It occasionally divides and unites again, particularly where it crosses from right to left, in the cavity of the thorax. The structure of this duct is similar to that of the lymphatic and chyliferous vessels; its parietes consisting of two membranes, an internal and external,—the former of which is thin and delicate, the latter is a strong, fibrous membrane, capable of opposing great resistance to a distending force.

In the thorax, lymphatic glands are found upon the diaphragm and pericardium, and around the thymus gland, and the large

vessels at the base of the heart. Besides these, there are numerous glands, situated before the division of the trachea, around the bronchia, and in the interior of the lungs.

In the superior extremities, these bodies are found at the bend of the elbow joint, and clusters of them surround the axillary vessels, and their branches, and the subclavian and carotid arteries. Several small glands, also, are found behind the ear, some upon the buccinator muscle, and along the base of the jaw. None have been found within the cavity of the cranium. The absorbent vessels of the left side of the head, and of the left upper extremity, terminate for the most part, in the thoracic duct, but partly in the left subclavian vein itself by two or three separate orifices. But the absorbents of the right upper extremity, open either into the right subclavian vein, or the internal jugular of the same side, and are frequently joined by the lymphatics of the right side of the head, and those from the right lung, forming a great lymphatic trunk on the right side. This, however, is very short, being seldom more than an inch in length.

The Function of Absorption.

The lymphatic system is a great apparatus, pervading, with few exceptions, every part of the body, and instrumental in a function indispensable to nutrition, and, consequently, to animal life. The function of absorption is chiefly concerned in two processes, diametrically opposite to each other, but each equally indispensable to the regular repair of the organization. One of them is the introduction of foreign substances into the circulation to be afterwards assimilated and identified with the living organs; the other, is the decomposition of the organs, and the regular removal of their *débris*, or detached molecules, in order to make way for the deposition of the new elements of nutrition. The lymphatics which originate in the mucous membranes of the alimentary canal, and the lungs, furnish the means by which the elements necessary to the repair of the organization, are introduced; while those which spring from the parenchyma of the organs, are the instruments by which these are regularly taken to pieces, to make room for their reconstruction by the nutrient vessels. Besides these functions, subservient to nutrition, the lymphatics absorb certain parts of the secreted fluids, both of those which are deposited upon surfaces which have no external outlet, and such as are secreted upon membranes, or in sacs, and canals, which are exposed to, or communicate with, the external air.

It appears, then, that the various absorptions which are regularly executed in the system, may be divided into the five follow-

ing kinds, viz. *alimentary*, *respiratory*, *interstitial*, *recrementitial*, and *excrementitial absorption*.

1. The first, or *alimentary* absorption, is executed at the inner surface of the small intestines. It is employed in the introduction of nutritious matter, obtained from the aliments and drinks, and its result is the formation of chyle.

2. The second, or *respiratory* absorption, is concerned in the introduction of an aerial principle, essential to life, into the mass of the blood. The consideration of it belongs to the history of respiration. By these two absorptions, all the materials introduced from without, for the support of life, are received into the system. These two species of absorption may be termed, collectively, *absorption of composition*.

3. *Interstitial absorption* is employed in regularly detaching from every organ a certain number of molecules, to counterbalance the action of its nutrient vessels, and thus to prevent an indefinite increase of its volume; or to preserve a proper equilibrium between composition and decomposition. It is this absorption which occasions the changes of volume in the organs, at the different periods of life; and when it predominates over nutrition, produces atrophy of particular parts of the body. It occasions the shrinking and disappearance of the thymus gland, the removal of exostoses and other tumours, and the disappearance of the red colour of the bones, in animals which have been fed for a certain time with madder. It is this, also, which hollows out a canal in the callus which unites a fractured bone. This absorption varies in every organ, and is of as many kinds as there are different tissues. Interstitial absorption may also be termed *absorption of decomposition*.

4. *Recrementitial absorption*. This takes up the fluids secreted upon surfaces which have no external outlet, which fluids would increase indefinitely if they were not removed by absorption, as fast as they are secreted. The matters taken up by this species of absorption are very various, as the serous fluids, the synovia of the joints, the serosity of the cellular tissue, the fat, the marrow, the colouring matter of the skin, that of the iris, and of the choroides, the humours of the eye, the lymph of Cotunnius, and the fluids exhaled into the interior of the lymphatic glands, and of the thymus and thyroid glands. The reality of this absorption cannot be denied, and is demonstrated by numerous facts. The quantity of the fat and the marrow of the bones, varies according to the age, and state of health, and various other circumstances. Dropsies disappear by absorption. If foreign substances, solid, liquid, or gaseous, be placed in contact with the surfaces which secrete these recrementitious fluids, they diminish, or totally disappear, by absorption; a fact which affords a presumption, that

the peculiar secretions of these surfaces must, in like manner, be subject to absorption.

5. *Excrementitial absorption.* The excreted fluids, also, are subject to absorption, by which they are deprived of certain parts which, perhaps, may be usefully employed in the system; or by the loss of which, they are rendered more fit themselves for the uses to which they are destined in the animal economy. A great variety of fluids are subject to this species of absorption, as, for example, the fluids exhaled by the skin, and the mucous membranes, the matter secreted by the sebaceous follicles, the mucus, the cerumen of the ear, the saliva, the bile, the gastric and pancreatic fluids, the spermatic liquor, the milk, and urine. Adelon remarks, that nature chooses to subject the materials of decomposition to a useful revision, before rejecting them finally from the body. By this absorption the excreted fluids become more concentrated and stimulating; hepatic bile is converted into cystic by absorption, the urine is rendered more acrid and concentrated; and the spermatic fluid becomes more stimulating by long retention. In general, only certain principles are absorbed from the excreted fluids; but if any obstacle prevents their excretion, they are absorbed entire, and may then be sometimes detected in the blood; and, in some instances, they are deposited, by a new secretion, in places remote from the organ by which they were originally secreted.

The absorptions which have thus been described, are carried on without intermission in the system; and they impress certain changes upon the fluids absorbed, by which these are prepared to contribute to the formation of the common nutritive fluid, the blood; for this fluid is the final result of the five species of absorption just enumerated. In each of these absorptions the matter absorbed is elaborated and changed in its properties. Thus, chyme is converted into chyle, by absorption. The oxygen absorbed in respiration is assimilated to the blood, so that it is impossible to detect its presence in this fluid. In like manner, the molecules detached from the tissues and organs by decomposing absorption, and the principles absorbed from the recrementitious and excrementitious fluids, do not preserve their proper characters in the lymphatics, but undergo an elaboration by which they are converted into lymph.

But absorption sometimes occurs accidentally, or occasionally; as for example, where certain substances which are not of an alimentary or assimilable nature, are introduced into the system, or placed in contact with any absorbing surfaces. Substances so circumstanced are frequently absorbed, and they may sometimes be detected in the blood, in the secreted fluids, or even in the parenchyma of the organs, for they undergo no elaboration, and their properties are unchanged by the action of the absorbents.

These accidental absorptions are of two kinds, viz. *External* and *Internal.*

The seats of the first, or of external absorption, are the two great surfaces, the skin and the mucous membranes. Substances of various kinds, placed in contact with either of these great expansions are subject to absorption, and may thus be introduced into the blood.

1. Solid, liquid, and gaseous substances, placed in contact with the skin, may be absorbed by this tissue, as is demonstrated by many facts. For example, thirst may be quenched by the application of moist cloths to the skin, or by bathing. Adelon cites the case of a patient in fever, in which so much water was absorbed during the use of a foot-bath, that the level of the fluid in the vessel was sensibly lowered. It is also asserted that the body increases in weight after using the bath, and that the urinary secretion is augmented, to carry off the water which has been absorbed. Cruikshanks witnessed the thirst quenched by bathing, and the secretion of urine, which had ceased in consequence of want of drink, restored by the bath. Falconer found that his hand, immersed to the wrist in warm water, had absorbed in a quarter of an hour ninety-eight grains of fluid. Hamilton observes that the saliva has become intolerably bitter from an absorption of sea-water. Paracelsus states, that he has supported patients by nutritive baths of milk or broth. Fontana and others assert, that the body absorbs moisture when exposed to a humid atmosphere. The experiments of Professor Mussey, performed several years ago at Philadelphia, demonstrate the absorption of the colouring matter of madder and other substances, by the skin. Medicinal substances, applied to the skin, are frequently absorbed into the circulation, and exert their peculiar effect upon the system. From the experiments of Chaussier, it appears that the hydrosulphuric acid gas is capable of producing asphyxia in dogs, when applied to an extensive surface of the skin. A plaster of garlic, applied to the skin, has been found to impart a strong smell of garlic to the breath and the urine, which continued several hours, though the individual breathed through a tube which passed out of the apartment. In general, however, the cuticle is previously removed, or the substance is applied by friction, or *rubbed* in; otherwise the absorption is much less considerable, for the cuticle appears to present an obstacle to the absorbing action of the skin. The cuticle, however, it should be remembered, opposes no resistance to the passage of fluids from within; and why, it may be asked, should it hinder the entrance of fluids from without. Metallic quicksilver has been found in the bones of persons who had been subjected to mercurial frictions; it has been found, for example, in a carious skull, and in some other of the bones. Autenrieth and Zeller obtained quicksilver by distilling

the blood of rabbits, dogs, and cats, which had been rubbed with this mineral. Schubarth had a large quantity of quicksilver rubbed into a horse, from the 5th of July to the 3d of August, when the animal died, and, on distilling his blood, small globules of quicksilver were discovered in it.* Canter obtained from the sediment of sixty pounds of urine, subjected to distillation, more than twenty grains of quicksilver. Quicksilver has been found, not only in the blood and urine, but in the saliva and sweat of persons who have been severely salivated. Many animals are nourished by cutaneous absorption, and the same may be true of the fœtus, in the first periods of pregnancy, before the mouth is formed by which fluids can be received, and when the intimate connexion between the fœtus and the mother does not yet exist. Gases also are absorbed by the skin. Thus, the putrid miasms of a dissecting-room have been absorbed by this membrane, as has been ascertained by experiment, in which precautions were used to prevent their introduction by pulmonary absorption. In a word, Westrumb inferred from his experiments that the skin possesses a faculty of absorption so extensive, that it can imbibe all kinds of substances, from the least to the highest degree of fluidity, provided they are soluble.

2. The mucous membranes also exercise an absorbing power upon various foreign substances placed in contact with them. Alimentary substances and air are constantly absorbed by the intestinal and the pulmonary mucous membranes. But other principles besides chyle and oxygen are absorbed from the aliments and the air which we breathe; as, for example, those parts of our food and drinks which are incapable of chylification, and the vapours or gases with which the air we inhale becomes accidentally impregnated. Substances not of an alimentary kind, also, introduced accidentally, or purposely, into the alimentary canal, such as medicines, colouring, odoriferous, saline, and other substances, are frequently absorbed. Chaussier produced asphyxia by injecting sulphuretted hydrogen gas into the intestines.

Accidental pulmonary absorption also is very active. Substances in a state of vapour, or fine dust, drawn into the lungs with the air of inspiration, are readily imbibed—such as metallic vapours, odoriferous substances, miasmatic exhalations, &c. Pulmonary absorption is, probably, one of the most frequent means by which contagious effluvia are introduced into the system. Liquids, also, injected into the lungs, are absorbed by these organs; a fact which has been established by repeated experiments.

The mucous membrane of the urinary and genital organs is also an absorbing surface. Fluids injected into the bladder are

* Rudolphi.

frequently absorbed; and the virus of syphilis is introduced into the system by the same channel of the genito-urinary mucous membrane.

But accidental absorption may take place from surfaces, or parts of the body, which have no communication with the external air. In fact, every part of the body seems to possess the power of absorbing substances placed in contact with it, as for example, the serous surfaces, the cellular tissue, and the parenchyma of the organs. Experiments have demonstrated that various substances, either in a solid, liquid, or gaseous form, are subject to absorption, if placed in contact with any tissue of the body, or even buried in the very substance of the organs. Chaussier inserted a calculus in a wound which he had made in an animal, and which afterwards healed over the foreign substance. After a time, the calculus became corroded, and finally disappeared by absorption.* Dupuytren and Magendie injected various liquid substances into the serous cavities and cellular tissue, and found that they were absorbed. Achard, Nysten, Chaussier, and others, had observed the same fact with respect to gases, as oxygen, carbonic acid, sulphuretted hydrogen, &c. introduced into different parts of the body. The air which escapes into the cellular tissue in emphysema sometimes disappears by absorption.

The excrementitious fluids, also, when their regular excretion is prevented by any obstacle, are subject to absorption. In jaundice, the bile is absorbed into the blood, and imparts a yellow tinge to all parts of the body. In paralysis of the bladder, and in the experiment of tying the ureters in a living animal, the urine is absorbed into the blood, and impregnates all the fluids and tissues of the system. Even the contents of the large intestines, if retained a long time, are partially absorbed, and impart a feculent odour to the cutaneous exhalation. Morbid excrementitious fluids, also, as pus, if long retained, are absorbed into the blood. The blood extravasated in the brain in apoplexy, or in any other part of the system, is sometimes absorbed. The crystalline lens is absorbed after the operation of couching in cataract; and even the fœtus, in extra-uterine pregnancy, is sometimes removed by absorption.

According to Adelon, *accidental* absorption is distinguished from *nutritive*, by the circumstance that in the former there is little or no change in the properties of the substances absorbed; whereas, in the latter, the matter absorbed is always elaborated in such a manner that its properties are disguised, and it cannot be detected in the fluids or solids of the system. Medicinal substances which are introduced into the system by accidental absorption from the skin or mucous membrane of the alimentary

* Adelon.

canal, retain their medicinal, properties nearly or wholly unchanged. Of this the following fact is a remarkable instance. Metallic silver was obtained by M. Brande from the plexus choroides and pancreas of an individual who had been cured of epilepsy by taking the nitrate of silver. The skin of the patient, who afterwards died of another disease, was coloured blue, and all the internal viscera were more or less stained with the same hue. If this were not the case, if medicinal substances were assimilated by absorption to the nature of the animal fluids, it is evident that they could not exert their specific effects upon the system. So the excrementitious fluids, when accidentally absorbed, retain their properties with little alteration. When the bile is absorbed in jaundice, or the urine, in retention of this fluid from paralysis of the bladder, or any other cause, these excretions impregnate the animal fluids and tissues with their own peculiar qualities.

Particular Absorptions.

It has already been observed, that there are five species of nutritive absorption, viz. *digestive* or *alimentary, respiratory, interstitial,* absorption of the *recrementitious* and that of the *excrementitious fluids.* The second belongs to the history of respiration, and the three last may be comprehended under a single title, viz. *internal absorption.*

1. Alimentary or digestive absorption, is executed in the small intestines. It is exercised upon the food and drink, after these have been subjected to the action of the digestive organs. The instruments of this absorption are the lymphatics of the small intestines, or *lacteals*, as they are called. These vessels originate in the villi of the mucous coat of the intestinal canal, and passing between the serous and muscular coats of the intestines, they proceed to the mesenteric ganglions. From these bodies there arise a second series of lacteals, fewer in number, but of a larger size, which unite together into larger trunks, and terminate, eventually, in the thoracic duct. There is a free communication between the lacteals which enter, and those which issue from the mesenteric glands, through these bodies; for, a mercurial injection passes from one to the other without distending the glands. It is doubtful whether the lacteals open directly into the cavity of the intestines, or, whether some kind of tissue exists intermediate between their extremities and the surface of the villi of the small intestines. However this may be, these vessels exert a peculiar vital action upon the chyme in the intestinal cavity, selecting, absorbing, and combining its nutritive principles, and converting them into a much more highly animalized fluid, termed chyle. This white, cream-like fluid, it is said, does not pre-exist

ready formed in the chyme, but is the result of the action of the lacteals upon the nutrient principles contained in it. It is affirmed, that chyle has never been discovered in the intestines, and that it is impossible to obtain it from chyme by expression or any other means. It is formed by the elaborating action of the lacteals themselves, which, at the same moment that they absorb, impress certain vital changes upon the nutritive parts of the chyme, which hence assume the properties of chyle. In the same manner, the sap of plants does not pre-exist in the soil in which they grow, but is formed by the peculiar action of the roots, which absorb the materials of it from the ground. No other substance but chyme which has been acted upon by the bile and pancreatic fluid, is capable of being converted into chyle; and such substances as find their way into the small intestines without being reduced to the state of chyme, do not contribute to the formation of chyle.

During digestion the lacteals become filled and turgid with chyle. Various theories have been proposed to explain the mode in which this absorption is accomplished. Some physiologists have referred it to imbibition or capillary attraction; some, to *endosmose* and *exosmose*, or the motion of heterogeneous fluids across a membranous diaphragm, separating them from each other; some, to electrical or galvanic agency; others, in fine, to a peculiar, inscrutable vital action. This last opinion, though it explains nothing, is, probably, the true one.

The action of the absorbents continues a considerable time after death, or the cessation of the circulation. After emptying some of the lacteals in an animal, soon after death, by pressing out their contents, they soon become filled again; and the experiment has been found to succeed two hours after the extinction of life. Mascagni observed absorption in infants to continue six hours after death, and in adults, twenty-four; and Desgenettes found it to take place sixty hours after the cessation of life, even in very young subjects. Valentin found chyle in the lacteals as late as three days after death.*

The quantity of chyle which is formed in a given time is uncertain. Magendie found, that in a dog of a common size, which had eaten heartily of animal food, more than half an ounce of chyle issued from an opening in the thoracic duct in five minutes, and it continued to flow out for several hours. This would imply a pretty rapid formation and motion of the chyle; for, at this rate, six ounces must have entered the circulation in an hour. Emmert estimated the quantity which flowed from the thoracic duct of a horse, at a pound in half an hour. In man, the

* Lepelletier.

quantity formed must be proportionally large, but it is evidently impracticable to arrive at any precision in estimating it.

The chyle appears to be constantly undergoing changes in its properties in its passage through the absorbent system. Its albuminous qualities seem to diminish, while the proportion of its fatty matter, and of its fibrin and cruor, appears to increase. Its tendency to coagulate also increases as it approaches the venous system, and becomes very considerable in the thoracic duct. In the large lymphatic trunks, or those between the mesenteric glands and the thoracic duct, the chyle gradually loses its opaque and milky or cream-like appearance, and becomes clearer and more transparent. It is also remarked by Emmert, that, in the smaller lacteals, near the origins of these vessels, the chyle is more homogeneous in its appearance and properties; but, in the larger trunks, it gradually becomes more heterogeneous. In the thoracic duct, it has sometimes been observed of a reddish colour. Chyle obtained from the smaller lacteals of a horse was found to be milk-white; while that from the larger trunks, and the receptaculum chyli, was yellowish; and the chyle of the thoracic duct still more so. Exposed to the air it assumed a pink or peach-blossom colour. These changes are probably produced, partly by the vital influence of the lacteals themselves, exerted upon the chyle, and partly by the action of the mesenteric glands. It is, however, impossible to determine, what are the functions of these bodies. It is conjectured, by some physiologists, that the chyle undergoes some peculiar modification in traversing these glands. Some are of opinion, that they produce a more intimate combination of the elements of the chyle; others, that they secrete a peculiar fluid, which is destined to dilute it; while some suppose that their office is to purify this fluid, by separating from it certain heterogeneous principles.

Absorption takes place throughout the whole alimentary canal. Even in the mouth the absorbents imbibe some part of the food, as is evident from the effects of wine or spirits held in the mouth. It is probable, also, that the absorbents of the œsophagus imbibe something from the aliment during its passage through this tube. The lymphatics of the stomach are found to be turgid during digestion. But the chyliferous absorbents of the small intestines are particularly active during digestion, in imbibing the nutritious chyle. These vessels diminish in number in the inferior portion of the small intestines; but some are found in the large intestines, and their effects are evident in the increasing density and consistency of the contents of the lower part of the alimentary canal. In horses and some other animals, the absorbents of the large intestines are observed to be filled with a chyle-like fluid.

As chyle is found only in the lacteals, and yet, as just observed, absorption of nutritious substances takes place from the whole surface of the alimentary canal, it appears that alimentary matter may be imbibed from the intestines, without having undergone the preparatory process of gastric digestion. Persons have been nourished for many days, and even weeks, by injections of milk, broth, and other nutritive fluids, thrown up the rectum. The author had a patient who was supported four weeks, *almost* exclusively, upon injections of animal decoctions and wine. No food whatever could be taken the greater part of this time. A few drops of sage tea, or even pure water, would occasion the most dreadful anguish; and it is a question with the author, whether food enough was swallowed, during this whole period, to form one gill of chyle. This patient completely recovered, and is now in the enjoyment of good health. Now, it is evident that alimentary substances, directly absorbed from the intestines, can undergo no assimilation previous to their reception into the circulation, except that which they receive in their passage through the absorbent system; a consideration which appears to establish the conclusion, that the absorbents exert an elaborating influence upon the substances absorbed, which, under some circumstances, may serve as a substitute for digestion in the stomach and small intestines; and it affords some corroboration of the principle that every living animal substance, solid as well as fluid, possesses a power of assimilation, by virtue of which it constantly tends to subdue to its own nature substances applied to or mixed with it, and to communicate to them its own properties. In cases of extreme irritation, it would seem that alimentary matter is sometimes absorbed so greedily as not to allow time either for chylification or any other considerable change to be effected. We are told of a young man almost dead of hemorrhage, supported by broth, in whom the last discharge of blood had the smell, taste, and even colour of this substance. He eventually recovered and grew fat. Lepelletier expresses the opinion, that hematosis, or the formation of blood out of the aliments, commences at the origin of the absorbents, that it is continued by the action of these vessels, by that of the mesenteric ganglions, and by the veins, and that it is finally consummated in the capillaries of the lungs, by the influence of respiration.

It has already been observed, that, after long fasting, the lacteals, instead of containing chyle, are filled with real lymph. But, according to Magendie, after twelve, twenty-four, or even thirty-six hours of total abstinence, the lacteals of a dog contain a small quantity of semi-transparent fluid, of a slightly milky appearance, which he supposes to be chyle, formed by the digestion of the saliva and the mucus of the stomach. But, if the

fasting be prolonged beyond three or four days, the lacteals are found sometimes filled with lymph, and sometimes entirely empty.

Venous absorption. Many physiologists of the present day, have adopted the opinion, founded on various facts and considerations, that the absorption of the chyle, and of other substances from the alimentary canal, is not effected, exclusively, by the lacteals. Some of the experiments and facts on which this opinion is founded will be noticed.

Magendie gave a dog four ounces of an infusion of rhubarb, and half an hour afterwards, not a trace of it could be discovered in the thoracic duct, though the urine of the animal indicated its presence, and half of it had disappeared from the alimentary canal. Segalas injected an infusion of nux vomica into a part of the intestines, isolated by two ligatures, having tied the blood-vessels of the part, but left the lacteals untouched. In one hour no appearance of poisoning had taken place; but in six minutes after removing the ligatures from the blood-vessels, symptoms of poisoning appeared. Berthold injected water, coloured with ink, into a piece of intestine of a puppy, isolated in like manner by two ligatures, and in ten minutes the fluid had partly disappeared from the intestine, and the veins of the part were filled with it, but the lacteals were entirely empty. According to Boerhaave, the blood of the mesenteric veins becomes more fluid during the digestion of fluids; and Flandrin thought that he perceived an herbaceous smell in the blood of these vessels, in a horse which had been eating food of this kind. Kaaw Boerhaave injected warm water into the stomach and intestines of a dog, just killed, and, by a little pressure, this water passed into the meseraic veins, so that these vessels became pale, and, at last, clear water flowed out of the vena cava inferior. The result was similar with coloured water. Lieberkuhn pushed an injection into the vena portæ, and saw the matter of it ooze out of the villi of the intestines. Ribes obtained the same result with essence of turpentine, coloured black, and with mercury—facts from which it appears, that the meseraic veins have open orifices in the cavity of the intestines. Flandrin gave a horse a mixture of honey and asafœtida, and the venous blood of the stomach and intestines exhaled the peculiar odour of the asafœtida, while the chyle and the arterial blood were wholly free from it. Magendie caused a dog to take diluted alcohol, a solution of camphor, and other odorous substances, and on examining the chyle half an hour afterwards, no trace of these substances could be detected in it; while the blood exhaled the odour of alcohol, camphor, &c. and these substances could be even obtained from the portal blood by distillation. The same physiologist gave a dog two ounces of a decoction of nux vomica, after tying the thoracic duct, and death

took place as speedily as in another which had swallowed the same poison without having had the duct obstructed by a ligature. In another dog, he isolated a piece of intestine by two ligatures, and divided, with the utmost care, all the vessels of the part, arterial, venous, lymphatic, and chyliferous, with the exception of a single artery and vein, which were left undivided. He then separated the piece of intestine from the rest of the canal, so that it was connected with it only by a single artery and vein, and injected into it a decoction of nux vomica, and in six minutes, the effects of the poison manifested themselves. Flandrin sometimes found the substances injected, in veins only; sometimes in the lacteals only, and sometimes in neither, but only in the urine. Haller found that the blue juice of the heliotrope, which he had injected into the stomach, was present in the chyle, but not the red colouring matter of madder, nor the yellow of saffron. Emmert showed that madder curcuma, prussiate of potash, nitrate of silver, &c. are received into the chyle.

The researches of Tiedemann and Gmelin, of Germany, and of Lawrence and Coates, of our own country, corroborate the conclusion, that absorption from the alimentary canal, is not exclusively the function of the lymphatics, but is shared with them by the mesenteric veins. In the experiments of Tiedemann and Gmelin, various colouring, odorous, and saline substances, were introduced into the stomach, and the urine, the portal blood, and the chyle of the thoracic duct, were afterwards submitted to the proper tests, or the presence or absence of the substances absorbed was ascertained by their colour or smell.

It appeared from these experiments, that colouring substances were not absorbed by the lymphatics or lacteals, as they could in no instance be detected in the chyle of the lacteals, or that of the thoracic duct, either by their smell, or by the aid of chemical tests, though they were detected in the urine, and in the serum of the blood of the *vena portæ;* facts which demonstrated that they entered the circulation by venous absorption. The same results were obtained with odorous substances. They were detected in the urine, and in the portal blood; but in no instance were they discovered in the chyle of the lacteals or thoracic duct.

Saline substances, of which several were employed, as the prussiate of potash, the muriate of barytes, the muriate and sulphate of iron, and the acetate of lead, were discovered in the urine, and several of them in the blood of the mesenteric veins; a *very* few of them, also, were detected in the chyle of the thoracic duct.

On the whole, they inferred from these experiments that the office of the lacteals is to absorb the nutritious matter formed by digestion, and to convey it to the thoracic duct; while the roots of the mesenteric veins absorb substances which are not of an

alimentary nature, as saline, colouring, odorous, and metallic, and, probably, medicinal and poisonous substances. Rudolphi, however, remarks in answer to these conclusions of Tiedemann and Gmelin, that nothing exists in the urine which did not previously exist in the blood. Now it is certain, that many substances can be detected in the urine which cannot be discovered in the blood. So in the chyle, many principles may be present, but not sufficiently concentrated to be detected by chemical or other tests. Roose proved, that the serum of the blood, as well as a filtered solution of the white of eggs, might contain a considerable quantity of oxide of iron in solution, without the possibility of detecting it by the usual agents; and he established the following principles, viz. that all organic substances, soluble in water, which are decomposed by exposure to a high temperature, possess the property of preventing the precipitation of the oxide of iron, and of other oxides, by alkalies; and on the contrary, all organic substances, soluble in water, which are completely or partially volatilized, *without decomposition*, by a high temperature, do not possess this power.*

The experiments of Lawrence and Coates led to results similar in the main to those of Tiedemann and Gmelin. The prussiate of potash was introduced into the stomach, and the blood of the *vena portæ* afterwards examined. On the addition of a salt of iron, the portal blood assumed a blue colour, more or less intense, indicating the formation of the Prussian blue. The chyle of the thoracic duct was also found to contain the prussiate of potash, evincing that the absorption of the salt had been effected partly by the lymphatics. In some of the experiments, the portal blood was found exclusively to contain the salt, the chyle of the thoracic duct presenting no trace of it; in some others, precisely the reverse of this occurred. But the authors remark, that the general weight of evidence was strongly in favour of the principal absorption having taken place through the *vena portæ*. The fact was more conclusively established by tying the thoracic duct, and thus intercepting the communication between the lymphatics and the circulation. In one experiment, in order to stop every known communication between the absorbent system and the circulation, the thoracic duct and the trunk of the lymphatics on the right side of the neck were both secured by ligature, yet the blue colour was produced in the serum of the blood, taken from the right side of the heart, in twenty minutes.

On the whole, it appears that the lacteals absorb chyle much more readily than other substances. Colouring, odorous, and mineral substances, perhaps poisons, and, in general, matters not of an assimilable nature, are absorbed with difficulty by the lac-

* Rudolphi.

teals, and much more easily by the veins. Some unchymified substances, of an alimentary nature, as milk, are absorbed by these vessels. Rudolphi says, that he has seen a whitish blood flow from the vessels of the head, in sucking puppies, on cutting into the diploe, from which blood a large quantity of bluish white fluid, perfectly like milk, soon separated itself. Lower also found milk in the blood drawn from a vein soon after food had been taken; and Veridet mentions a case, in which a person in an attack of fever drank a quart of milk, and on bleeding him soon after, a stratum of milk formed on the blood. In cases of long fasting, the lacteals absorb the animal juices, and become filled with intestinal fluid, bile, &c. and frequently with true lymph.

Several distinguished physiologists assert a direct communication between the absorbent vessels and the veins. Blizard and Meckel observed lymphatics terminate directly in veins. Ribes, in injecting the supra-hepatic veins, saw the matter pass into the superficial lymphatics of the liver. According to Mertins, a considerable part of the chyle is carried directly into the *vena azygos*, and the lumbar veins, and others by the lacteals. Meckel, Lobstein, and others, have observed similar communications with the vena portæ; and other physiologists have asserted their existence in various other parts. Lizars remarks, that some of the lymphatics, almost as soon as they originate, join the veins in the capiliary tissue; others anastomose with the veins in the lymphatic glands, while a third class concentrate to form the thoracic duct. Aselli, the original discoverer of the absorbent system, was persuaded that the lacteals terminated in the vena portæ; an opinion which, according to Mayo, the observations of Fohman have proved to be partially true, showing that many of the lacteals open into the branches of the visceral veins. It is also said that a Dr. Dubled of Paris has succeeded in injecting the two inferior thirds of the thoracic duct, and some of the neighbouring lymphatics, by forcing an injection through the inferior vena cava. He also found, in an animal in which he had tied the vena cava below the diaphragm, that the thoracic duct, and some of the lymphatics, a few hours afterwards, contained blood. But an Italian anatomist, Lippi, has carried this opinion to a much greater extent. He has endeavoured to prove, that the absorbent vessels of the abdomen open freely into the iliac, the spermatic, the emulgent, and lumbar veins, and the vena cava, as well as into the branches of the portal system; and that they communicate with the venous system, not only by opening into the great venous trunks, but by anastomosing with the small veins which issue from the conglobate glands, and by direct continuity with the capillary veins. He also affirms, that several absorbent trunks in the abdomen terminate directly in the pelvis of the

kidneys. He does not think that any communication exists between the absorbents and veins in the limbs. This alleged communication between the absorbents and the veins, is regarded by many physiologists as imaginary. Rudolphi treats the opinion with contempt, but Mayo observes, that he thinks it not unlikely that such communications do exist, even in the limbs; for he has sometimes seen mercury thrown into the absorbents of the limbs unaccountably make its way into the veins. He also states, that on injecting the arteries of the mesentery of a dog with ink, he observed the veins next to become filled with a black fluid, and then the lacteals; and he further says, that he has certainly seen, in one instance, the absorbents of the liver filled with coloured injection from the hepatic artery. Adelon doubts the reality of this communication, and regards it as a cadaveric phenomenon. According to Camper, and Tiedemann and Gmelin, there are numerous anastomoses between the chyliferous vessels and the meseraic veins. In experiments performed by these two last named physiologists on two dogs, a horse, a cow, and three human bodies, the lacteals were injected with quicksilver; and in all of them the metal reached the branches of the mesenteric veins, and the vena portæ, without the application of any external force. On close examination, it was discovered that the communication of the lacteals with the veins of the intestines, took place in the mesenteric glands, and that all the veins proceeding from a gland filled with quicksilver, also became filled with the metal; a fact which proved, that it passed from the lacteals through the gland directly into the veins proceeding from it. In several of their experiments, these physiologists observed in the portal blood, white streaks resembling chyle, and which they supposed to be really such; an appearance which was readily explained by their discovery of a communication between the lacteals and the meseraic veins, in the glands of the mesentery. The chyle, thus entering the portal circulation, and conveyed with it to the liver, they supposed to be elaborated in this gland, by the separation of its heterogeneous principle in the secretion of bile.

Rudolphi, however, gives no weight to the experiments in which quicksilver has been observed to pass out of a gland into a vein. He supposes, in these cases, that this ponderous metal forced for itself new passages. He admits that quicksilver, injected into an absorbent, frequently passes into a vein; but he explains the fact by asserting that either the vein lying under or near the absorbent has been wounded by the injecting tube, or, what he says is most frequently the case, that the quicksilver has passed from the absorbent vessel into the thoracic duct, left subclavian vein, through the superior vena cava into the inferior, and thence to the place where the injection was made. This

passage of the injected quicksilver through the thoracic duct, superior and inferior cava, &c., takes place, he asserts, in a moment. Rudolphi further objects, that if such communication really existed between the veins and lymphatics it would be impossible to inject the latter with quicksilver, for all the metal would pass into the veins. He admits that in birds, anatomists at present regard the immediate communication of the absorbents with the veins as fully established. When the lymphatics in a duck's foot are injected with quicksilver, the metal is *always* soon found in the lumbar veins. But he says that it is impossible to discover the communication. On opening the vein no orifice of a lymphatic can be detected in it; but the lymphatic may be traced to the kidney; and here, he thinks, the connexion exists by which the quicksilver gets into the veins. He supposes that, in the kidneys of birds, which are very large, a particular connexion may exist between these two orders of vessels. This important question cannot yet be considered as settled; though, to the author, the arguments in favour of the communication of the absorbents and the veins appear to preponderate.

It appears that the thoracic duct may be obstructed, and yet chyle find its way into the circulation. In two instances, Sir A. Cooper found this canal obstructed in human subjects; but in both collateral vessels ascended from below the obstruction, and opened into the duct above it. Dupuytren tied the thoracic duct in horses, some of which died, while others survived the operation. In one, which was opened six weeks after the operation, the canal was found perfectly closed at the place where the ligature was applied; but there were found connecting vessels, which passed from the part of the duct below the ligature to the subclavian vein. But in an experiment performed by Leuret and Lassaigne, the thoracic duct of a dog was tied, and the animal lived and even thrived fifty-eight days, at the end of which time he was killed; and upon opening him, the thoracic duct, which was single, was found perfectly closed. The accuracy of this statement seems to be doubted by Rudolphi, and very naturally, as, if admitted, it appears decisive of the question of the passage of chyle into the circulation by other channels than the thoracic duct. Flandrin repeated the experiment of tying the thoracic duct on twelve horses, which lived and retained their flesh and appetite. On killing and opening them a fortnight afterwards, he found that the thoracic duct was not double.

The passage of the chyle into the left subclavian vein, it is said, takes place only by drops; and the conversion of chyle into blood is effected, not at once, but by degrees, and after many revolutions of the blood through the circulating system. Haller thought that eighty thousand revolutions of the blood were necessary to complete the conversion of chyle into this fluid.

Plocquet says, that chyle requires ten or twelve hours in order to be converted into red blood; and Autenrieth adds, that in blood drawn from man, or other animals, within this time, the serum is sometimes found milk-white. In this view, it is apparent that the secretions and excretions, particularly urine, by removing the unassimilable principles from the imperfect blood, may contribute essentially during its circulation through the body to its complete sanguification. The opinion, that the chyle is not immediately converted into blood, is founded partly on the appearance of white streaks and flakes which have sometimes been observed in the blood a few hours after digestion. These streaks Haller took to be chyle. He had even seen, in living animals, white chyle, floating in the blood, issue from a wound or enter the heart. This white appearance, however, disappeared some hours after eating, and the whole mass of the blood resumed its usual red colour.

In some instances, instead of the blood presenting the appearance of white streaks or flakes, the whole mass of it has been observed to be coloured white, presenting the appearance of milk or cream, for a longer or shorter time. This appearance of the blood has been observed in individuals of scorbutic or cachectic habits, or of corpulent persons.

These appearances of the blood probably depend on different causes. When occurring a few hours after eating, the white streaks are, perhaps, owing to unassimilated chyle, especially when fat, oily, or milky food has been eaten, and the powers of digestion and hematosis are enfeebled. In other cases, they may be owing to pathological states of the blood, as in scurvy, chlorosis, or, as Hewson supposed, to the absorption of fat, milk, pus, or other substances. Emmert regards this appearance, not as chyle, but as a sign of an inflammatory condition of the blood, and analogous to the pleuritic crust.

Internal absorption. From the analogy in structure of the lymphatics with the lacteals, which unquestionably absorb a nutritive matter from the intestines, from the lymphatics constituting a part of the same system of vessels, and from the universality of their distribution, it has been inferred that their office is to absorb and to convey to the circulation the elements detached from the organs, and certain principles separated from the secreted and excreted fluids. The direct proofs of this function of the lymphatics, however, are not perfectly conclusive; and one of the most eminent physiologists of the age considers the general doctrine as resting on insufficient grounds. Some of the most important facts in favour of lymphatic absorption are the following:

Whenever acrid or poisonous substances, as, for example, the venereal virus, are imbibed into the system, or when a person,

in dissecting a dead body, is accidentally inoculated with the septic poison, with which corpses are sometimes tainted, it is generally the lymphatic system which first discovers marks of irritation. The lymphatic vessels, originating near the part to which the poison is applied, frequently become inflamed, presenting the appearance of red lines, and the lymphatic glands, to which they lead, sometimes become enlarged and tender.

Mascagni found in animals which had died of pulmonary or abdominal hemorrhage, the lymphatics of the lungs and peritoneum full of blood. He also observed, in one instance, all the lymphatic vessels filled with the fluid of a dropsy. Desgenettes observed the lymphatics of the liver to contain a bitter lymph, and those of the kidneys lymph impregnated with urine. Soëmmering saw the lymphatics of the liver filled with bile, and those of the axilla with milk. And Dupuytren observed the lymphatics and the lymphatic glands, in the neighbourhood of a large suppurating tumour, situated at the internal part of the thigh, filled with a fluid which had the characters of pus.* In caries of the bones, according to Soëmmering, the lymphatics, in that vicinity have been seen filled with calcareous earth. Hunter injected water, coloured with indigo, into the peritoneum; and saw the lymphatics of the abdomen assume a blue colour. The extirpation of the lymphatic ganglions, if practised immediately after the insertion of certain poisons, or infectious matters, prevents the absorption of the latter in the corresponding parts. So, in cases of extravasation, the lymphatic vessels, which originate in the seats of the extravasated fluid, become engorged with it. In the experiments of Lawrence and Coates, which consisted in injecting certain substances, as the prussiate of potash, into the cavity of the abdomen, the chyle of the thoracic duct was found to contain this salt. When it was injected into the trachea of a living animal, its presence was detected in one case in the thoracic duct; and in two or three instances, indications of its presence were detected in the right side of the heart. In another curious experiment, a saturated solution of prussiate of potash was injected into the cellular tissue, over one side of the abdomen, and the same quantity of a strong solution of sulphate of iron was thrown into the cavity of the abdomen, on the opposite side. In thirty-five minutes the animal was bled to death; and on examination the lungs were found to be of a deep blue colour throughout their whole texture. The *thoracic duct*, in its course in the thorax, was of a deep blue; the *chyle* contained in it, the urine, and the coagulable lymph of the blood, were all blue. The day after, the chyle had thrown down a blue deposit. Mascagni mentions an experiment which he made upon himself,

* Adelon.

and which appears decisive of the question of lymphatic absorption. Having immersed his feet several hours in water, he observed a slightly painful tumefaction of the inguinal glands, and a transudation of the fluid through the gland.

From these and other similar facts, the absorbing function of the lymphatics is almost universally admitted; but several distinguished physiologists have revived the ancient doctrine of venous absorption, contending that the veins share this function with the lymphatics; and one eminent experimentalist has attempted to prove, that absorption is the *exclusive* prerogative of the veins. The subject of absorption, in relation to the mesenteric veins, has already been considered. If it be true that these veins partake with the lacteals in the office of absorbing substances from the alimentary canal, analogy would justify us in concluding, that the veins in other parts of the system must participate with the lymphatics in the same function. A well-known experiment of Magendie, has been considered as placing the doctrine of venous absorption beyond controversy. He separated the thigh of a dog from the body, dividing all the parts except the femoral artery and vein. Into each of these vessels, he introduced the barrel of a small quill, upon which each of the vessels were secured by two ligatures, and then divided, in a circular direction, between the ligatures; so that the two columns of blood, flowing in opposite directions in the femoral artery and vein, constituted the only vital connexion between the limb and body of the animal. Two grains of a very subtle poison were then forced into the cellular substance of the foot, and in about four minutes, the poison manifested its peculiar effects upon the animal. This experiment, however, does not appear absolutely decisive of the question, because in forcing the poison by a blunt instrument into the cellular substance of the foot, some of the small veins must unavoidably have been lacerated; and in this way a portion of the poison directly introduced into the returning blood. Or, the poison might have been imbibed by the coats of the veins. The experiments of Lawrence and Coates demonstrate the absorption of the prussiate of potash from the lungs, by the pulmonary veins, the salt being detected in the left side of the heart in a few minutes after being injected into the trachea. According to Mayer, also, the prussiate of potash, injected into the lungs, is found in the blood sooner than in the chyle, and sooner in the left than in the right side of the heart. Yet when large quantities were injected, it was found largely in the venous blood of the right side of the heart, and in the inferior vena cava.*

Absorption from the cellular tissue by veins, was also demon-

* Rudolphi.

strated by Lawrence and Coates, by repeating the experiment of Magendie, with the variation of substituting the prussiate of potash for a powerful poison. The result was equally striking, but like the other, perhaps, not wholly free from fallacy.

In their experiment upon the prussiate of potash, injected into serous cavities, they found that absorption was accomplished principally, if not exclusively, by the lymphatics.

Magendie states that himself and Dupuytren had made more than one hundred and fifty experiments, in which they had exposed a great number of different fluids to absorption, by the serous membranes, and that they had never seen them find their way into the lymphatics. The substances thus introduced into the serous cavities, produced their peculiar effects upon the system, with the same promptitude when the thoracic duct was tied, as when this canal was left unobstructed. Opium stupified; wine intoxicated; &c.

To these facts it may be added, that foreign substances applied to a granulating surface, have afterwards been discovered in the blood of the veins, but not in the lymphatics.

One important fact remains to be noticed, viz. that pus is sometimes found in veins coming from the vicinity of an abscess, a fact which appears to prove that it was absorbed by these vessels. Bourdon relates a remarkable case of this kind, in a man who died shortly after undergoing amputation of one of his thighs, on account of a fall which shattered his limbs to pieces. His peritoneum was found highly inflamed; and on examining the amputated limb, the vena saphena was discovered to be full of pus, or rather it contained more pus than blood. In the iliac vein the proportion of blood was greater, yet even in this vessel there was found a good deal of pus. The veins on the opposite side also were filled with pus along the whole course of the leg and thigh. In pursuing the dissection of the whole limb very carefully, on arriving at the foot, a considerable effusion of pus was discovered, which was beyond all doubt the source of that found in the veins of the leg and thigh, and which reached as high up as the iliac vein.

Adelon is of opinion, that both veins and lymphatics are concerned in internal absorption, interstitial, recrementitious, and excrementitious. These two orders of vessels, he observes, are equally extended from the parts where absoption takes place, to the centre of the circulation. They are both *returning* systems of vessels, and have their origins at the external and internal surfaces, where absorption occurs. An injection thrown into a vein or lymphatic, equally penetrates into the parenchyma of the organs, and oozes out at the surfaces, which are the seats of the recrementitious function. The lymph and the venous blood, which circulate in these two orders of vessels, have the same

destination, viz. after being blended with the chyle, which is another product of absorption, to be converted in the lungs into arterial blood. The lymphatics and the veins have equally a capacity superior to that of the arteries; and hence there are the same reasons to believe that both of these orders of vessels return to the centre of the circulation *something more* than the residue of the arterial blood. Both of them also are provided with valves; and they are connected with each other by numerous anastomoses. All that seems to be necessary to complete the analogy between these two orders of vessels, is to suppose that their essential functions are the same, and that on the one hand the veins participate in what has usually been regarded as the peculiar function of the lymphatics, viz. absorption, and on the other, that the lymphatics exercise an office analogous to that of the veins. The grounds of the first of these opinions have already been noticed, and they have proved satisfactory to the minds of many physiologists. The second, viz. that the lymphatics are not only absorbents, but veins, has also been adopted by some physiologists, and supported with very plausible reasons. This opinion regards the lymphatics as the veins of the white or colourless tissues, as cartilage, tendon, ligament, the serous membranes, &c. These tissues in the healthy state are not supplied with red blood. They receive only colourless vessels circulating a white albuminous fluid. If the white tissues, however, are attacked with inflammation, these colourless vessels become sufficiently enlarged to carry red blood, and are then visible to the naked eye. Now the doctrine of the venous function of the lymphatics supposes that these vessels carry back the residue of the colourless fluids from the white fluids, just as the veins return the residual or venous blood from the red. Adelon is of opinion that the materials of internal absorption are not merely imbibed, but are changed into lymph and venous blood at the moment of their absorption. Venous blood, he says, is as much formed by venous absorption out of the materials absorbed by the veins, as chyle is by the lacteals out of chyme. Neither lymph nor venous blood exists before the action of absorption.

Several distinguished physiologists, however, are of opinion, that substances which find an entrance into the veins, are not absorbed by the mouths of these vessels, but penetrate through their coats by *imbibition.* Mayo mentions the following facts, most of them taken from Magendie, in favour of this opinion. A piece of fresh meat put in common salt, in a few days becomes penetrated throughout its whole mass with salt. In an animal opened some time after death, the parts in the vicinity of the gall-bladder are found deeply tinged with bile. If the theca vertebralis be opened in a living animal, or soon after death, it is found to contain a certain quantity of fluid; but a like quantity of fluid is not

found in it if the examination be delayed till some time after death. If half an ounce of acidulated water be thrown into the pericardium of a dog killed twelve hours before, and a continual stream of warm water be injected into the coronary arteries, so as to flow into the right auricle, in four or five minutes it gives unequivocal evidence of containing an acid. In an animal killed by a poisoned arrow, the parts near the wound become impregnated, to the depth of several lines, with a brownish yellow colour, with the bitter taste belonging to the poison.

That imbibition takes place in living animal matter also, is established by many facts. If a drop of ink be put on the peritoneum of a living animal, it soaks into it, and forms a large circular stain, which penetrates through the membrane, and after a considerable time, to the subjacent tissues. If a small quantity of ink be introduced into the pleura of a puppy, in the course of an hour the pleura, the pericardium, the intercostal muscles, and the surface of the heart itself, assume a blackish tinge. If the jugular vein of a living puppy be raised from its place and separated from the neighbouring parts by a piece of card, and the vessel be carefully denuded of the surrounding cellular textures, and a strong aqueous solution of the alcoholic extract of nux vomica be placed upon the middle of the card, so as to surround and bathe the vein, the usual effects of the poison manifest themselves in less than four minutes. Magendie found the same results to follow when the experiment was made on a large arterial trunk; only they were much less prompt, owing to the greater thickness of the arterial coats, and the superior compactness of their texture. More than a quarter of an hour was necessary for the passage of the nux vomica through the coats of the artery. Emmert saw all the symptoms of poisoning with prussic acid produced in a couple of rabbits, by applying the oil of bitter almonds to the sound skin of the back. The muscles under the skin, even as deep as the bones, had the smell of the prussic acid.

The effect of suction, of ligatures, and of the application of cupping glasses in preventing the absorption of poison, are all favourable to the idea, that it finds a passage into the system by imbibition.

Magendie ascertained the fact, that a state of distention of the vessels is unfavourable to imbibition. He injected a large quantity of water into the veins of a dog, and having introduced a poison into the cavity of the pleura, he waited nearly half an hour to witness its effects, which in other cases required only about two minutes to manifest themselves. He then bled the animal largely in the jugular vein, and as the blood flowed, the poison began to manifest its effects. Hence he concluded that absorption is inversely as the distention of the vessels. On the same principle, perhaps, absorption is promoted by inanition,

exhausting discharges, and all causes which diminish the mass of the fluids, or retard the motion of the blood. Hence medicines act with most power if given in the morning on an empty stomach. Exposure to contagion is said to be most dangerous under the same circumstances. Absorption is very active after long sickness, after the operation of purgatives, after blood-letting, and long fasting. Intoxication is most apt to occur *cet. par.* in hungry, feeble, and exhausted persons. On this principle, probably, depends the quicker disappearance of extravasated blood, dropsical effusion, &c. under a scanty diet.

Magendie conjectures that the cause of imbibition is the affinity of the coats of the vessels for the substances absorbed. The serous membranes, and the cellular tissue, according to the same physiologist, are, particularly during life, the best agents of imbibition.

Fodéra ascertained that imbibition is very much accelerated by galvanism. A solution of prussiate of potash was injected into the pleura, and a solution of sulphate of iron, into the abdomen of a living animal. Under ordinary circumstances, five or six minutes are required for the two substances to come into contact, by imbibition through the diaphragm. But if a light galvanic current were transmitted through the diaphragm, the passage took place instantaneously. The same result was obtained, when one of the solutions was placed in the urinous bladder, and the other in the abdomen; or one in the lungs, and the other in the cavity of the pleura.

It appears, on the whole, that the subject of venous absorption, is involved in no little obscurity, though the facts and considerations in favour of this alleged function of the veins, appear to preponderate over those of a contrary tendency. Whether, however, substances which obtain an entrance into these vessels are absorbed by open orifices, or are imbibed by their coats; or whether they find their way thither by both these avenues, is a question of secondary importance. The great fact seems to be fully established, that many foreign substances find their way into the system, principally, if not exclusively, by this channel, and whether they owe this prerogative to a vital or a physical cause, is evidently of no consequence; since, in either case, the result, as far as we know, is the same, and the means of effecting it were undoubtedly not a matter of accident, but of choice.

Admitting the reality of venous absorption, we shall have three classes of vessels endowed with the function of absorption, viz. the lacteals, lymphatics, and veins; and from the wise frugality of nature in the use of means in accomplishing her intentions, it may be rationally inferred, that each of these systems of vessels performs a distinct and peculiar office in the general function of absorption. Dr. Handyside of Edinburgh, accordingly, has

attempted to allot to each its appropriate office in the following positions, founded on experiments made either by himself or by other physiologists:

1. That the lacteals absorb aliment, and nothing else.

2. That the lymphatics absorb the *débris* of the body, or the molecules which have become useless, and must be removed to make room for the deposition of new matter.

3. That the veins, besides returning the blood to the heart, absorb various foreign substances.

Lymph is obtained with difficulty from the lymphatic vessels, on account of the tenuity and transparency of these vessels, and the circumstance that they are not always filled with this fluid. It may, however, be obtained from the thoracic duct of an animal which has been kept from food for three or four days. It then presents the following characters. It is a nearly transparent colourless fluid, or, according to some physiologists, of a slightly opaline colour, tinged with red. Its rose colour is said to be deeper the longer the animal from which it is taken has fasted. It has a strong spermatic odour, and a saline taste.

The motion of the lymph is slow. When one of these vessels is punctured, the lymph is said to issue out very slowly. The lymphatics possess a contractile power, and frequently empty themselves as soon as they are exposed to the air. Hence they are almost always found empty in an animal recently dead. Their contractile power may probably be assisted by the mechanical compression, which they undergo from the contraction of the neighbouring muscles; from the pulsation of the arteries with which they are in contact; from the pressure of the distended hollow organs, and other causes; and the motions there impressed upon them, and communicated to their contents, are determined by the disposition of their valves in the direction of the thoracic duct, when it mingles with the chyle.

The conglobate glands have been supposed to perform the office of more completely assimilating the heterogenous principles which enter into the composition of the lymph, and perhaps of arresting and separating any noxious ingredient, so as to prevent its passage into the blood-vessels. In favour of this last conjecture, may be mentioned the swelling of the conglobate glands, which lie in the course of branches of the lymphatics, by which poisonous or noxious substances have been absorbed. In these cases, which are of common occurrence, the poisonous substance appears to be arrested in its course to the circulation, by the lymphatic gland, which it irritates and inflames, and which sometimes suppurates, a process by which the poison may be destroyed or evacuated. Or, if suppuration should not take place, the noxious principle may be neutralized or assimilated, by the

peculiar action of the gland, and thus disarmed of its power of doing mischief.

In certain situations, or under particular circumstances, the lymphatic glands become coloured. Thus the glands which receive the lymphatics of the liver are of a yellowish colour, derived probably from the colouring matter of the bile. The bronchial glands are black; the mesenteric glands of animals fed with madder, become red; facts which render it probable that the colouring matter is arrested in its course to the circulation, and perhaps, after a time, assimilated or destroyed by the peculiar action of the gland.

CHAPTER XVIII.

SECRETION.

In speaking of the fluids of the system, it was observed that they might be divided into three classes, viz: 1. those which serve for the preparation of the blood; 2. those which are formed out of the blood; and 3. the blood itself. The first and the last of these, viz. the chyle, lymph, and the blood, have already been described. It remains in this place to consider the second class, viz. those formed out of the blood, or the *secreted* fluids, and the process by which they are prepared, or the FUNCTION OF SECRETION.

Secretion may be defined *the vital action of the secretory organs upon the blood, by which they extract from it, and combine together, the elements of a fluid which had no existence in the blood previous to this elaboration.* This function is one of the most obscure and mysterious in the animal economy. The vessels subservient to it Mr. Hunter used to call the architects and chemists of the system, expressing by these terms the plastic powers of these agents, which, out of the same homogeneous fluid, the blood, could construct such a variety of wonderful fabrics, and compound such a diversity of chemical products.

The vital nature of the function of secretion is evident from many facts and considerations. The division or compression of the nerves, distributed to a secretory organ, is said to suspend this function, and the peculiar fluid prepared by the organ, we are told, is no longer secreted. The secretions are also liable to great variations in their degrees of activity, and in their results, from the peculiar condition of the vital powers of the secretory organs. Hence the secreted fluids are constantly changing, not

only in quantity, but in their qualities, in consequence of the fluctuations occurring in the state of the vital powers of the glands, which prepare them. Moral causes, as is well known, have a powerful influence upon the secretions. Sorrow and profound grief pervert the qualities of the bile. A fit of anger sometimes causes an increased secretion of this fluid. The same passion has also been known to produce such a change in the qualities of the milk, in a nurse, that the child which she suckled was frequently seized with vomiting and convulsions; a fact which, Lepelletier says, he had often witnessed.

Morbid states of the secretory organs materially affect the qualities of the fluids prepared by them. Thus the cellular membrane, and several of the other surfaces, when inflamed, secrete pus; the pleura and peritoneum, when in the same morbid state, secrete fibrin, and sometimes pus. The bile in a diseased state of the liver, differs materially from the healthy fluid; and the secretion of the kidneys becomes exceedingly depraved in certain diseases of these organs.

In its simplest form secretion seems to be merely a separation of some element or principle already existing in the blood. In this manner a serous fluid is separated from the blood, and deposited upon certain surfaces by a kind of arterial exhalation. This kind of secretion may be illustrated by a fact, which is observed when the body is injected with size and vermilion thrown into the aorta; for then there is found in the serous cavities a quantity of colourless size, which must have been strained through very minute orifices.* That this is not a mere mechanical filtration, however, is evident from the fact, that when membranes, which in their healthy state are lubricated by a serous exudation, become diseased, the fluid exhaled by them differs materially in its properties from the healthy secretion. Warm water injected into the veins, also, filters through serous surfaces.

It has been ascertained by experiment that the blood contains, ready formed, some of the principles which exist in certain of the secretions, as well as some of the peculiar kinds of animal matter of which the organs are composed. Thus fibrin, or the basis of muscular flesh, is one of the elements of the blood. A peculiar substance, ascertained to be the basis of nervous matter, has also been detected in the blood. Some of the elements of the bile, also, have been discovered in the serum of the blood. Another curious fact discovered by Prevost and Dumas is, that after the extirpation of the kidneys, a sensible quantity of *urea* may be found in the blood; from which it has been inferred that the kidneys do not form this substance, but only separate it from the blood. If this were the case, however, it seems difficult to

* Mayo.

account for the fact, that not a trace of urea can be found in the blood of animals who have not undergone this operation. Another curious fact of a similar kind is, that the blood of a frog, after the extirpation of the testicles, has been found capable of fecundating the female spawn. From the imperfect state of animal chemistry, it is probable that several principles may exist in the blood, which our present means of analysis will not enable us to detect. Dupuytren injected two ounces of bile into the veins of a dog, but the blood of the animal, which was analyzed a few moments afterwards by Thenard, exhibited not a trace of bile.*

If it could be proved, however, that all the substances of which the secreted fluids consist, pre-existed in the blood, it would not follow that the process of secretion is a mere mechanical separation of these substances from the blood. It would still be necessary to suppose some peculiar elective power in the vessels of the secretory organs, by which the peculiar secretion of each gland should be separated from the mass of the blood, and collected in the excretory vessels of the gland. No mechanical filtration would be adequate to separate the *neurine* or *cholesterine* from the blood; or to select the numerous principles which are formed in the urine, and to combine them together into this fluid. The process must be a chemico-vital, or dynamic one, even in the simplest case of secretion; a conclusion which is confirmed by the fact, that secretion is so much influenced by the state of the vital or nervous power of the system at large, or of the secreting organ itself.

But with respect to much the greater part of the secreted fluids, we have no evidence that they pre-exist in the blood. They cannot therefore be considered as *educts*, but must be regarded as the *products* of secretion. We must consider them as formed by the secretory vessels, out of principles furnished by the blood, which these vessels themselves have the power of selecting out of the general mass, and of combining together into new compounds. Of the nature of the process, or the means employed by the secretory vessels in accomplishing it, we are wholly in the dark. Wollaston conjectured that electricity may have some agency in secretion, an idea which he illustrated by a very ingenious experiment. He took a glass tube, about two inches long, and three quarters of an inch in diameter, and closed one extremity with a piece of bladder. He then poured into the tube a little water, containing, in solution, a minute quantity of muriate of soda. After moistening the bladder, he placed it on a bit of silver; then bent a fine zinc wire, so that one of its extremities touched the piece of silver, and the other penetrated into the tube, to the depth of about an inch. At the same moment the

* Lepelletier.

external surface of the bladder indicated the presence of pure soda. There was, therefore, from this very weak action of the electric fluid, a decomposition of the marine salt, by which the soda was separated from the acid, passed though the bladder, and was deposited on its external surface.

Dr. Young suggests an explanation of the mode in which electricity may be supposed to act in the process of secretion. "We may imagine," he observes, "that at the subdivision of a minute artery a nervous filament pierces it on one side, and affords a pole positively electrical, and another opposite filament, a negative pole; then the particles of oxygen and nitrogen, contained in the blood, being most attracted by the positive point, tend towards the branch which is nearest to it, while those of the hydrogen and carbon take the opposite channel; and that both these portions may again be subdivided, if it be required, and the fluid, thus analyzed, may be recombined into new forms, by the reunion of a certain number of each of the kinds of minute ramifications. In some cases the apparatus may be somewhat more simple than this; in others, perhaps, much more complicated."*

The structure, or organization, by which secretion is effected, is of three kinds:

1. The first and simplest consists merely of capillary vessels, minutely ramified. This kind of structure is employed in the separation of those fluids which are designed to moisten and lubricate certain cavities and surfaces of the body. Thus, the pleura and peritoneum are kept moist by a serous fluid, separated from the blood by this simple kind of structure. There is some difference of opinion among anatomists respecting the disposition and nature of these vessels. Some suppose that they consist of the ultimate divisions of the arterial branches. Others suppose that these vessels are pierced with a great number of lateral pores, through which the secreted fluids exude. But Bichat, and many other modern anatomists, assume the existence of a particular order of vessels, proceeding from the capillary arteries, denominated *exhalants,* of a peculiar texture and properties, and giving passage, in the healthy state only to white or colourless fluids. These exhalant vessels are supposed to possess some peculiarities of structure and properties, in each of the different tissues of which they form a part. Hence the differences which exist in the fluids exhaled from the skin, the mucous, serous, and synovial, &c. membrane, viz. the sweat, the exhalations in the mucous cavities, the serosity which lubricates the serous sacs, &c. The fluids exhaled by these vessels are deposited either on surfaces which communicate with the external air, and are eliminated from the system in the form of a fluid or vapour,—or, in closed cavities, from which they are again taken into the

* Med. Literat. p. 109.

system by absorption. The fluids thus separated by exhalation, or perspiration, from the blood, may be reduced to the following heads; 1. *cutaneous*; 2. *mucous*; 3. *serous*; 4. *synovial*; 5. *cellular*; 6. *medullary*; 7. *ocular*; 8. *vascular*.

2. Another kind of structure, one degree more complicated, is that of the *glandular follicles*. These are small, bottle-shaped sacs, lodged in the substance of the membranes in which they are situated, with their mouths opening on the surface of these membranes. Their cavities are lined by a continuation of the mucous membrane, which is supplied with a considerable number of nerves and blood-vessels. The external coat of the follicles appears to possess a certain degree of contractility, since the expulsion of the matter secreted by them is accomplished by the contraction of these bodies themselves. Indeed, Haller supposed that they possessed muscular fibres analogous to those which exist in the urinary bladder. The fluid secreted in these cavities remains some time, during which its consistency is gradually increased by the absorption of its more fluid parts. But when the membrane in which they are seated is irritated, and requires to be moistened, they contract and expel the fluid they had secreted.

Mucous follicles, or *crypts*, are found only in the membranes of relation, viz. the mucous membranes, and the skin. They open only on the free surfaces of these membranes, and this circumstance, together with the unctuous quality of the follicular secretions, sufficiently proves that they are designed to lubricate these membranes, and to screen them in some degree from the contact of foreign substances, to which, as membranes of relation, they are constantly subject. There are three kinds of fluids prepared by follicular secretion, viz. *mucus*, *sebaceous matter*, and the *cerumen* of the ears.

3. The third, and most complicated kind of structure, subservient to secretion, is that of the conglomerate glands. These are large organs of a peculiar structure, which constitute several of the viscera. They are formed by a large number of arteries, veins, nerves, and lymphatics, disposed in a peculiar manner, and connected together by a tissue of cellular membrane. When contained in a cavity, they are invested on their external surface with a coat derived from the membrane which lines the cavity; and they are provided with a canal, called the excretory duct. This duct, throughout all its ramifications in the gland, is lined with mucous membrane.

With regard to the ultimate structure of glands, anatomists have been divided in opinion. Malpighi maintained that the parenchyma of glands is formed of hollow granules, or *acini*, each of which might be considered as a follicle, intermediate between the termination of the blood-vessels of the gland, and the origins of the excretory ducts. Ruysch, on the contrary,

contended, that these acini were nothing more than inextricable plexuses of blood-vessels, and excretory ducts continuous with them, and that secretion is accomplished at the place of their communication. The opinion of Rusych, according to Blumenbach, is much the most consistent with microscopical observations, and the effects of minute injections. Still, some anatomists are of opinion that some peculiar kind of structure, or parenchyma, exists in the glands intermediate between the blood-vessels and excretory ducts; and that this parenchyma presents the peculiar and characteristic part of the organ in which its secretory function is performed; and that it varies in its structure and physiological properties in each species of gland. Besides this fundamental tissue of the glands, arteries, veins, lymphatics, nerves, excretory ducts, and cellular tissue, to connect the whole together, enter into the structure of these organs.

Some of the glands are provided with a reservoir, or membranous sac, in which the product of their secretion is deposited for a time, and its essential principles concentrated by the absorption of its aqueous parts. These sacs are lined interiorly by a mucous membrane, and externally they are formed of a membrane which some anatomists have considered as of a muscular nature, since it possesses the power of contracting, and thus of expelling from its cavity the secreted fluid deposited in it.

The phenomena of glandular secretion may be reduced to the four following. 1. Excitation of the gland, during which the blood flows to it in increased quantity. 2. The peculiar action of the glandular parenchyma, or secretion, a chemico-vital process, *sui generis*. 3. The deposit of the fluid, secreted in the reservoir of the secretion. This fluid immediately after its secretion is absorbed by the radicles of the excretory duct, is transmitted through this canal by means of its insensible contractility, and deposited in the reservoir, if one exist; otherwise, it is conveyed by the excretory duct to the place of its destination. 4. Excretion. While the secreted fluid is detained in the receptacle, it becomes more concentrated by the absorption of its thinner parts, by which it is rendered more exciting to the walls of this cavity; while, by its increasing accumulation, it acts as a physical stimulus. The parietes of the receptable at length react, by their contractility, upon the secreted fluid, which is gradually forced out of the cavity; and, in some instances, certain muscles, subservient to the excretion, are excited sympathetically into action, to promote the expulsion of the secreted matter. In some cases, excretion as well as secretion is excited by a stimulus, acting upon the interior of the canal into which the excretory duct opens.

The glandular secretions may be divided into the seven following kinds, viz. the *lachrymal*, *salivary*, *pancreatic*, *biliary*, *lactic*, *urinary*, and *spermatic*.

Classification of the Secreted Fluids.

The secreted fluids have been classified on different principles. 1. According to their composition, or chemical nature. 2. According to their destination and uses in the animal economy. 3. According to their degree of cohesion or consistency. 4. According to the structure of the organ by which they are secreted.

I. In relation to their composition, the secreted fluids may be divided into five classes, viz.—

1. The *serous*, or watery, resembling the serum of the blood, and composed of a large proportion of water, a little albumen in solution, and salts, existing in the latter. To this class belong the serosity of the serous membranes, and of the articulations, that of the cellular tissue, of the chambers of the eye, of the capsule of the crystalline lens, and of the labyrinth of the ear.

2. The *albuminous*, distinguished by the presence of a large quantity of albumen. To this class belong the pancreatic and spermatic fluids, and the milk, which contains, besides a serous fluid, an oily matter, and several salts.

3. The *mucous*, which are characterized by the presence of a large proportion of animal mucus; as the mucus of the mucous membranes, that of the mouth, fauces, stomach, intestinal canal, nose, air-passages of the lungs, and urinary and genital organs; and, in most animals which live in the water, the fluid which lubricates the surface of the skin.

4. The *fat* or *oily*, as the fat of the cellular tissue, the marrow of the bones, the fluid secreted by the crypts, or follicles of the skin, the cerumen of the ears, the secretion of the meibomian glands, and the sebaceous matter of the prepuce.

5. The *mixed*, as the saliva, the bile, the urine, the tears, which contain several salts and peculiar animal principles.

II. In respect to their uses in the animal economy, the secreted fluids have been divided into two classes, viz. the *recrementitious*, and the *excrementitious;* the first, including those which are destined to be absorbed, and returned into the mass of blood, and which are deposited in cavities which have no external outlet; the second, comprehending those which are designed, after their formation, to be expelled from the system, and which are deposited in cavities, or on surfaces, which communicate with the external air.

To the first class, or that of the recrementitious secretions, belong the exhalations into the cellular membrane, and the serous cavities; the synovial fluid, the oily fluid of the cellular tissue, and that of the round bones, and the aqueous humour of the eye. The excrementitious secretions may be divided into two orders, viz. those which, though destined to be discharged from the system, are yet designed to perform certain offices before their

removal; and, secondly, such as are strictly and exclusively excrementitious, and which serve no other purpose than to depurate the blood. The first order embraces the saliva, the gastric fluid, the bile, milk, and several others. The latter comprehends the urine, and the exhalations from the skin and lungs.

Berzelius has made the interesting remark, that the secretions, or the fluids destined to be employed within the system for particular purposes, are alkaline; while the excretions, or those destined to be evacuated, are all acid. To the excretions, Berzelius refers the urine, the fluid of perspiration, and the milk. All the others belong to the class of secretions.

This observation of Berzelius, however, has been contradicted by Schultze, who says, that he has not found it verified in any species of animal. The same secreted fluid, he says, in one kind of animal is acid, in another alkaline, in a third indifferent, as he has ascertained by more than a hundred experiments; whence he conceives it impossible to establish any general law on the subject.

Thus, of the *secretions;* the bile is an alkaline fluid, containing, besides various salts, and some animal principles, a small quantity of uncombined soda. The spermatic fluid also contains about one per cent. of free soda. The tears, the saliva, and the pancreatic fluid, all contain the same alkali.

On the other hand, the excreted fluids, the urine, the matter of perspiration, and the milk, are all characterized by possessing acid properties. They all contain a free acid, which, according to Berzelius, is the *lactic.* Milk contains six parts in one thousand of this acid, besides various salts, in some of which, it exists in a state of combination. The matter of perspiration also contains a small portion of acid, which Thenard considers as the acetic, but Berzelius conceives it to be the lactic acid. The skin, also, exhales carbonic acid. That the urine is an acid fluid, is evident from the fact, that recent human urine reddens litmus paper, an effect which, according to Berzelius, is owing to the presence of lactic and uric acids, in a free state; but, according to Dr. Prout, depends on two super-salts, which exist in the urine, viz. the superlithate, and superphosphate of ammonia.

The halitus of pulmonary exhalation, which may be regarded as one of the excretions, affords another exemplification of the principle of Berzelius. This vapour contains carbonic acid; and this, as it is generally supposed, is produced by the acidification of the carbon of the venous blood. A curious fact, first mentioned by Bichat, may be referred to the same principle. If a solution of phosphorus be injected into the veins of an animal, fumes of phosphoric acid are poured forth from the lungs, formed by the acidification of the phosphorus in the pulmonary exhalants.

Tiedemann observes, that, between the secreted and excreted

fluids, there exists this difference, viz. that the former contain globules, or organic molecules, of which no traces can be discovered in the latter. Thus, globules have been found in the saliva, the pancreatic and the spermatic fluids, and the milk, which he ranks among the secretions; while none have been discovered in the urine, the bile, the tears, &c. The bile and tears, it will be observed, Tiedemann assigns to the excretions.

III. In relation to their degree of cohesion and consistency, the secreted fluids may be divided into the *aeriform* and the *liquid.* To the first class belong the exhalations from the skin, and the organs of respiration. All the other secretions belong to the second, or that of the liquid secretions. These, however, differ exceedingly in their consistency. Some of them, as the serosity of the serous membranes, and that of the cellular tissue, the aqueous humour of the eye, and the liquor of Cotunnius, are nearly as fluid as water, though their specific gravity is greater. Next to these in cohesion, may be ranked the tears, the urine, and sweat. The saliva, the pancreatic fluid, the bile, the mucus, synovia, milk, and the spermatic liquor, possess a still greater degree of consistency, and some of them are viscid and ropy. But the oily secretions, as the fat, the marrow of the bones, the cerumen, and the matter secreted by the follicles of the skin, are still more consistent, and even require a certain degree of heat to render them fluid.

IV. The secreted fluids, considered in reference to the structure of the organs by which they are prepared, may be divided into three classes, viz. the *perspiratory*, or, *the exhalations*, the *follicular* and the *glandular*.

The perspiratory secretions, or the exhalations, take place either in cavities which have no external opening, or on the skin, or mucous membranes. Hence, they have been divided into *exterior* and *interior* exhalations. The exterior exhalations comprehend those of the mucous membranes and of the skin; the interior, the serous, synovial, cellular, medullary, ocular, and some others. The exterior exhalations will be considered first.

Cutaneous Exhalation, or Perspiration.

The secretion from the skin is an albuminous halitus, or vapour, which is perpetually exhaled from its outer surface, and is termed, the insensible perspiration, though it possesses qualities which frequently fall under the notice of the senses.* It often has

* Dr. Edwards has shown, that the skin performs a function analogous to respiration; and that animals of the frog kind will live longer deprived of their lungs than of their skin. Under the former mutilation they were found to live several days; in two cases out of three, thirty-three days; under the latter, or the loss of the skin, they lived only a few hours.

a sensible odour, and frequently, instead of assuming the form of an invisible vapour, it is deposited on the skin in drops of a colourless liquid, which is called sweat. The instruments of this exhalation, are the numerous exhalant arteries, which enter into the texture of the skin, and open upon the surface of this membrane. According to Breschet and De Vauzeme, the skin is provided with a distinct apparatus for the secretion of the cutaneous fluid, consisting of a glandular parenchyma, and of canals for conveying the secretion to the surface of the body. These excretory canals are disposed in a spiral form, and open obliquely under the scales of the epidermis. The process of cutaneous exhalation goes on without intermission during life. The fluid is constantly issuing from the skin in the form of a vapour, which is immediately dissolved by the air, or absorbed by the clothing, and forms a kind of atmosphere round the body.

When condensed into a liquid, the matter of perspiration is a colourless fluid, heavier than water; and is composed of water, a small quantity of free acetic acid, hydrochlorate of soda and potash, a little phosphate of lime, a little animal matter, and carbonic acid; and, according to Thenard, a trace of oxide of iron.* The presence of a free acid in it is sometimes very evident, from its rank sourish smell. The matter with which the skin becomes incrusted, where habits of cleanliness are neglected, was analyzed by Vauquelin and Fourcroy, and found to consist almost wholly of phosphate of lime. The animal matter is the source of the peculiar odour which distinguishes different animals, and which varies, probably, in every individual of each species. This odour is subject to many variations, from a variety of circumstances, as the age, temperament, sex, nature of the aliments, use of medicine, healthy or pathological state, &c. In jaundice, it is said that the cutaneous transpiration has the odour of musk; in scrophulous persons that of sour mucilage; in scurvy, the smell of sulphuretted hydrogen; and in the latter stages of many fatal diseases, that of animal matter in a state of putrefaction;† characters, which might perhaps be turned to account in the diagnosis of many diseases. The peculiar odour, with which the cutaneous perspiration becomes tainted in certain diseases, is owing to the presence of certain principles which become accidentally combined with it. Thus Orfila, according to Lepelletier, demonstrated the presence of bile in the sweat of patients affected with the jaundice. The cutaneous transpiration in putrid

* It appears that not only carbonic acid, but azote also, is exhaled by the skin; and according to Abernethy, in the proportion of two parts of the former, to one of the latter; and we are informed by Collard de Martigny, that a full diet of animal food increases the proportion of azote, while a diet of vegetable food, or of white meats, causes an increased proportion of carbonic acid.

† Lepelletier.

fevers, contains, according to Deyeux and Parmentier, *ammonia*, and in milk fever, according to Berthollet, a free acid. A very curious fact in relation to the odour of the cutaneous exhalation is mentioned by Speranza, an Italian physician. A man of a robust constitution, after a hard day's work, perceived that his left fore-arm exhaled from its internal surface, a peculiar aromatic odour, like that of the Peruvian balsam, or the vapour of amber or benzoin thrown upon ignited coals. This odour was extremely powerful, so as even to impregnate the chamber in which he slept; and it was increased by friction. It continued two months and then disappeared after a violent attack of fever.

It is difficult to ascertain the amount of this secretion. Many experiments have been made on the subject, but with contradictory results. It is unquestionably one of the most abundant of the excretions, and some have estimated it to exceed all the rest collectively. According to Dodard, it averages in France, an ounce every hour; and bears to the solid excretions the ratio of seven to one, and to all the excretions together, that of twelve to fifteen. According to Robinson, in Scotland the cutaneous perspiration in youth bears to the urine the ratio of 1340 to 1000, or obout 3½ to 10, and in old age, that of 967 to 1000. Sauvages states that sixty ounces of ingesta, furnish five ounces of fæces, twenty-two of urine, and thirty-three of cutaneous perspiration. It is much influenced in its amount by season, climate, age, manner of life, sickness, health, and probably other circumstances. Thus, in the warm months of the year, the cutaneous secretion has been found to bear to the urine the proportion of five to three; but in the cold months not to exceed that of two to three. In the temperate months, the two excretions have been observed to balance each other. In old age, the urinary secretion exceeds that of the skin, and the reverse is true in infancy. The cutaneous exhalation exceeds the pulmonary in the ratio of about eleven to seven.

According to Lavoisier and Seguin, the greatest quantity of the insensible perspiration is thirty-two grains a minute; equal to three ounces, two drachms, and forty-eight grains an hour; and five pounds a day. Its smallest amount is eleven grains a minute, or one pound eleven and a half ounces a day. Its average quantity is estimated at eighteen grains a minute, of which eleven are furnished by the skin, and seven by the lungs.

Several other estimates, founded on observation, have been made by other physiologists, which do not differ materially from those of Lavoisier and Seguin. Mr. Dalton, however, in a series of experiments which he performed on this subject, arrived at very different results.

Mr. Dalton found that in the month of March, his daily consumption of solid food was thirty-eight ounces, and of fluid, fifty-

three ounces; amounting in the whole to ninety-one ounces, or nearly six pounds. During this time he evacuated daily forty-eight and a half ounces of urine, and five ounces of fæces, leaving thirty-seven and a half ounces, or about two-fifths of the whole to be accounted for, which must have been lost by cutaneous and pulmonary exhalation.

In the month of June a similar series of experiments gave somewhat different results. The solids consumed per day amounted to thirty-four ounces; the fluids, to fifty-six ounces; total, ninety ounces. Daily evacuations of urine, forty-two ounces, of fæces, four and a half ounces; leaving nearly forty-four ounces, or almost one half, for the daily loss by cutaneous and pulmonary exhalation.

According to Mr. Dalton's estimate, the whole amount of the insensible perspiration from the whole surface of the body, is only one-fifth of the quantity exhaled from the lungs. He found that he exhaled from his lungs 2.8 lbs. troy, of carbonic acid, containing nearly ten ounces and a quarter of carbon, in twenty-four hours. He also ascertained that he exhaled not exceeding twenty and a half ounces of aqueous vapour, making the whole amount of water and carbon discharged from the lungs in one day thirty ounces and three quarters. This taken from thirty-seven and a half ounces, the total of cutaneous and pulmonary exhalation, leaves only six ounces and three quarters per day for the insensible perspiration, consisting of six ounces and a half of water, and a quarter of an ounce of carbon.

In Dalton's experiments, about an ounce and a half of azote were taken into the stomach daily, in the form of flesh, cheese, and milk; and nearly the whole of it, or rather about the same quantity must have passed off by the kidneys and intestinal canal.

It appears, therefore, that Dalton differs very widely in his estimate of the amount of the insensible perspiration, from other physiologists who have investigated the subject. While the latter estimate it at more than thirty ounces, Mr. Dalton reduces it to less than one quarter of this quantity; and while they calculate that the cutaneous exhalation exceeds the pulmonary in the ratio of eleven to seven, Mr. Dalton infers that the pulmonary is five times as great as the cutaneous.

The cutaneous exhalation, it appears, attains its maximum during the six hours before noon; it falls to its lowest point immediately after eating, and again increases during digestion. According to Edwards, it is increased by sleep, by a dry state of the air, and by exposure to heat. He also supposes it to be influenced by atmospheric pressure. Impaired digestion is said to diminish it very much; yet the author has known a case of very severe and obstinate dyspepsia, in which during digestion the sweat would fall in large drops from the ends of the fingers.

Here it may be observed, that whatever quantity of food a person may take, and whatever increase of weight he may acquire after eating, if he has attained his full growth, and is in good health, he always returns, after the expiration of twenty-four hours, to the same weight.

In general, insensible perspiration is most abundant in infancy, when it is sourish to the smell; and least so in old age. It is more abundant in men than in women, in whom it becomes acid during menstruation. It increases in summer, diminishes in winter, and is much more copious in hot than in cold climates. It also varies much with the degree of excitation of the skin. When this organ is directly excited by friction, or sympathetically, from its connexion with the organs, the cutaneous exhalation is much increased. When the blood contains a large proportion of water, this function frequently becomes more active; and the same is true when some of the other excretions are not performed with their usual activity; the defects being compensated by the increased activity of the cutaneous exhalation. If the quantity of the insensible perspiration increases, that of the urinary and intestinal excretions is diminished. The quantity of the blood is another circumstance which influences this secretion. Plethoric persons frequently perspire copiously. Exercise, by increasing the velocity of the blood, is frequently accompanied and followed by sweating. Magendie mentions a person who could always bring on sweating while in bed, merely by forcibly contracting his muscles for a few moments. Taking warm drink is often followed by sweating. A circumstance which points out the influence of the nervous system upon this function is, that certain mental emotions, as fear and great perplexity of mind, are sometimes attended with profuse sweating.

Certain parts of the body perspire more easily and more copiously than others; as for example, the hands and feet, the axillæ, the groins, the forehead, &c. These parts receive proportionably a greater quantity of blood than others, and some of them are secured from the contact of the air, as the axillæ and the soles of the feet. This exhalation also differs in its odour, and perhaps in its composition, in different parts of the body. Its acidity seems to be greatest in the axillæ, as appears from the red stain it frequently communicates to blue garments, under the arm-pits.

As certain circumstances, especially a dry state of the air, and a diminished barometrical pressure promote both physical evaporation and insensible cutaneous perspiration, Edwards has been led to distinguish in this function of the skin, two elements, viz. a vital and a physical one, or secretion and evaporation. On placing frogs at a lower temperature both in a dry and a moist air, and comparing the losses of weight which they suffered in these different circumstances, the fluid lost by secretion,

compared with that which disappeared by transpiration, appeared to be in the ratio of one to six; from which it may be inferred that we lose much more fluid from the skin by evaporation than by secretion.

The uses of this function in the animal economy are various. It is evident that it is subservient to the decomposition of the body. It depurates the blood of carbonic acid, and many saline ingredients, like respiration and the renal secretion, and with this last it has an intimate connexion. In many animals it is the only excretion subservient to the decomposition of the organs; as no apparatus for the secretion of the urine exists in them. Another important use of this secretion is, to absorb and carry off the excess of animal heat, and to prevent the elevation of the temperature of the body above the natural standard. It serves also to maintain the epidermis in a state of suppleness favourable to the exercise of the sense of touch. Its importance in the animal economy may be estimated from the fact that its suspension is a frequent source of disease, and its restoration one of the most usual signs of returning health.

Mucous Exhalation or Perspiration.

The mucous membranes are the seat of an exhalation analogous to that of the skin. These membranes are the seat of two orders of secretions, one perspiratory or exhaling, the other follicular. The instruments of the first, or the exhalations, are the capillary vessels, termed the mucous exhalants, which open upon the surface of these membranes, and which must be carefully distinguished from the follicles, which secrete the mucus with which these surfaces are lubricated. The perspiratory fluid of the mucous membranes has a close analogy with the serum of the blood. It is a thin diaphanous fluid, of a greater specific gravity than water, and of a slightly saline taste, consisting of muriates and phosphates of potash and soda, albumen, and a little mucus dissolved in a large quantity of water. This humour is constantly exhaled at the surfaces of the mucous membranes, which it contributes to moisten and lubricate; and perhaps aids at the same time in depurating the blood. Examples frequently occur of a morbid increase of this secretion, as, for instance, at the commencement of nasal and pulmonary catarrhs, in which the discharge is generally thin and serous; and in serous diarrhœa and choleras, in which the quantity of serous fluid discharged is sometimes uncommonly great.

The perspiratory exhalation of the *conjunctiva*, a perfectly transparent fluid, mingles with and dilutes the tears, serves to moisten the conjunctiva, and prevent its irritation by the contact of the air, and facilitates the motion of the eyeball, and of the

palpebræ upon each other. In the serous ophthalmia it is increased; in the dry, suppressed.

That of the nasal passage performs a similar office in guarding the mucous membrane of the nose from the irritating contact of the air, maintaining it in a requisite degree of moistness and suppleness for the sense of smelling, and perhaps dissolving the odorous particles which are drawn into the nose in the act of smelling. This exhalation is frequently increased at the commencement of *coryza;* and diminished or suppressed at the invasion of an acute inflammation of the mucous membrane of the nose, and of many other acute phlegmasiæ.

The cavity of the *tympanum* is lined by a detachment of the mucous membrane of the fauces, which is also the seat of a perspiratory secretion, designed to keep the parts contained in this cavity in a condition favourable to the exercise of their functions. An increase of this exhalation produces dropsy of the tympanum; a suppression occasions a preternatural dryness of it.

The membrane which lines the interior of the *excretory ducts* of the *mammæ*, is the seat of an active exhalation, particularly during the process of lactation. It unites with and dilutes the milk secreted by the glands, and facilitates its excretion. In some cases this membrane becomes the seat of a sanguineous discharge, vicarious of the menstrual secretion.

In the sexual and urinary organs, both male and female, the perspiratory secretion of the mucous membranes which lines them, serves to moisten these passages, and to facilitate the various functions of which they are the seats. In the female organs, this exhalation is much augmented after parturition, and takes the name of the *lochial discharge.* In chronic inflammation of the uterus or vagina, it is frequently increased, producing a discharge, termed *fluor albus* or *leucorrhœa.* Sometimes the membrane which lines the uterus becomes the seat of a gaseous exhalation, which escapes from its cavity with an explosive noise.

The mucous membrane of the *alimentary canal*, in its whole extent, is the seat of an active exhalation, by which these passages are moistened and lubricated, their contents diluted, and their various functions facilitated. This exhalation is much increased during the processes of mastication, deglutition, and gastric and intestinal digestion. In the stomach, the product of this exhalation is termed the gastric fluid, which is possessed of peculiar properties, and is the great agent of chymification. In certain morbid affections of the stomach this exhalation is increased, and gives rise to vomiting or eructations of serous fluid. In the small intestines it takes the name of the intestinal fluid, serves to dilute their contents, and probably to promote the solution of the nutritious parts, which were not digested in the sto-

mach. A morbid increase of it gives rise to serous diarrhœas. In the large intestines, the fluid exhaled by their mucous membranes serves to dilute the feculent matter, and to facilitate defecation. A morbid increase of it may occasion serous diarrhœa; its diminution, a hard and dry state of the fæces, accompanied with obstinate constipation.

The *lungs*, also, are the seat of a mucous exhalation which keeps the pulmonary passages constantly moist, though exposed to the drying influence of the air. Like the dermoid exhalation, it assumes the form of a vapour by absorbing a large quantity of caloric, and is probably one of the means of preventing the temperature of the lungs from rising too high, from the animal heat generated in respiration. In certain diseases of the lungs, as the humoral asthma and serous catarrh, the pulmonary exhalation is increased. The dermoid and pulmonary exhalations are probably vicarious of each other. If either is diminished, the defect may be compensated by the increased activity of the other. Thus Delaroche and Berger, having covered the whole skin with a varnish impermeable to the sweat, found that the loss of weight was not diminished, by obstructing the exhalation from the skin.

Internal Exhalations.

1. *The serous.* The serous membranes, or those which line the serous cavities, are the seats of a constant exhalation, destined to keep these membranes moist, to facilitate the gliding motions of their contiguous surfaces upon each other, and to prevent their adhesion. The exhaling vessels, which open upon the free surface of these membranes, are the sources of this exhalation. It is a transparent, colourless fluid, having a greater specific gravity than water, with little taste; and is composed of albumen, hydrochlorates, subcarbonates, and subphosphates of potash and soda, and a gelatinous mucus, dissolved in a large quantity of water. It differs from the serum of the blood, according to Bostock, principally in containing a less proportion of albumen and of water. A trace of osmazome has been found in the serum of the ventricles, of the brain in hydrocephalus, and in the cephalo-spinal fluid of a horse.* A morbid increase of this exhalation gives rise to dropsies of the serous cavities. In inflammations of the serous membranes, this exhalation frequently becomes so much loaded with albumen, that it forms layers of coagulated matter over the inflamed surfaces, which sometimes become organized into false membranes, and frequently cement the contiguous surfaces together.

The serous membranes secrete from the blood with great

* Magendie.

promptness foreign substances introduced into it. This was found to be the case with the hydrocyanated ferruret of potass, introduced into the jugular vein of a horse by Herring. It appeared first on the internal surface of the pericardium, then successively on the pleura, the peritoneum, and lastly on the articular capsules of the extremities. No trace of the solution was found in the ventricles of the brain in the few instances in which they were examined. From two to fifteen minutes elapsed before it made its appearance in the other serous cavities.

The cavities in which this exhalation takes place are those of the *arachnoides*, the *pleuræ*, the *pericardium*, the *peritoneum*, and the *tunica vaginalis*.

The *cephalo-spinal* exhalation, according to Magendie, is one of the most abundant and most important, though least known. It is found beneath the arachnoides, covering the whole surface of the brain, filling up the depressions which this presents, and forming a layer of variable thickness, which extends from the cranium to the extremity of the sacrum. It also exists in the ventricles of the brain and cerebellum, which are lined by a prolongation of the arachnoides.

The quantity of this fluid, according to Magendie, varies with a variety of circumstances. In general, it is in the inverse ratio to the volume of the brain. In atrophy of this organ, from old age, or any other cause, the quantity of the cerebro-spinal fluid is augmented, so as to keep the cranio-spinal cavity constantly full, and when any part of the brain is wanting, its place is occupied by this fluid. The morbid increase of it in the ventricles of the brain constitutes the disease termed *hydrocephalus;* its accumulation in the cerebro-spinal canal is called *hydrorachis.*

In the cavities of the *pleuræ*, the serous exhalation serves to maintain the moisture of the free surfaces of those membranes, and to facilitate their motions upon one another, in the play of the lungs in respiration. Its morbid accumulation constitutes the disease termed *hydrothorax.*

The *pericardium*, also, is moistened by a serous exhalation, designed to facilitate the motions of the heart. Dropsy of the pericardium is the result of its morbid increase.

In the cavity of the abdomen, the exhalation from the *peritoneum* maintains the surfaces of all the organs, contained in this great cavity, in a state of humidity favourable to their free motions, and prevents adhesion between contiguous surfaces. The morbid increase of this exhalation, gives rise to one of the most frequent and most incurable forms of dropsy, *ascites.*

The *tunica vaginalis*, also, is moistened by a serous exhalation, which, when morbidly increased, gives rise to *hydrocele.*

2. *The Synovial.* The synovial membranes lining the movable articulations, and the sheaths of the tendons, have a close analogy

with the serous membranes, and are the seat of an exhalation designed to facilitate the motions of the joints, and the play of the tendons in their sheaths. The product of this exhalation is called the synovia. It is a white or yellowish viscid fluid, having some resemblance to the white of an egg, of a slightly saline taste, and is composed of a large proportion of albumen, a fatty matter, a peculiar animal substance soluble in water, soda, muriates of soda and potash, and phosphate and carbonate of lime. Its use is to lubricate the joints, for which purpose its smoothness and viscidity admirably adapt it, performing the same office in animal mechanics, as the oil which we apply to those parts of artificial machines which are exposed to friction. It is sometimes morbidly increased, giving rise to *hydrarthrosis*, or dropsy of the articulations.

3. *Cellular.* The cellular tissue, so generally diffused throughout the system, is the seat of a double exhalation, one *serous*, the other *adipose*. The plates of which this tissue is composed, are constantly exhaling into the cells which they form, a fluid which has a close analogy with that of the serous membranes, and which, probably, is subservient to the same uses, viz. to facilitate the play of these plates upon one another, and thus to favour the motions of the various organs which are connected together by cellular tissue. In some parts of the system, where the fat might be inconvenient or injurious, we meet with the cellular tissue wholly isolated from the adipose system; as, for example, in the cranium, the spine, the eyelids, the organs of generation, round the vessels, &c. A morbid increase of this exhalation constitutes that form of dropsy called *anasarca* or *œdema*.

Besides the serosity of the cellular tissue, there is found, in many parts of it, a fluid of a very different nature, called *the fat.* Magendie remarks, that some parts of the cellular tissue always contain this substance; other parts, sometimes only; and others again, never. The orbit of the eye, the soles of the feet, the pulp of the fingers, and that of the toes, *always* contain fat. The subcutaneous cellular tissue, and that which surrounds the heart, the kidneys, &c. *frequently* contain it; while that of the eyelids, the scrotum, and of the interior of the brain, are always destitute of it.

The fat is contained in distinct cells, which have no communication with those adjoining them; a circumstance which, Magendie observes, has led to the opinion, that the tissue which secretes the fat is different from that which exhales the serosity. The correctness of this opinion he thinks doubtful. The size, the form, and the disposition of these cells, are extremely variable, and the whole quantity of fat which they contain, not less so. In some individuals it amounts to a few ounces only; in others, to some hundred pounds.

According to Chevreuil, human fat is always of a yellowish colour, inodorous, lighter than water, and insoluble in this fluid; of an unctuous consistence, and becoming concrete at variable temperatures. It is very inflammable, and becomes rancid by the action of air and light. To the microscope it presents the appearance of polyhedral granules, enveloped in a very fine diaphanous membrane. Animal fat is composed of two parts, one fluid, at common temperatures, the other concrete, composed of two proximate principles, in different proportions, termed by Chevreuil, *elaine* and *stearine*. According to the relative proportions of these two elements, the fat is more or less fluid at a common temperature.

The uses of this substance, in the animal economy, are chiefly of a physical kind. It lubricates the solids, and facilitates their movements. In the orbit of the eye it forms a soft, elastic cushion, on which the eyeball moves with facility. In the soles of the feet, and on the buttocks, also, it forms a cushion, which diminishes the effect of pressure, to which these parts are so much exposed. It is also supposed to contribute to maintain the animal heat, and to guard against the effect of severe cold; since fat substances are bad conductors of caloric. The seat of the sensation of cold, however, is not the parts within the subcutaneous adipose matter, but the skin, which, of course, cannot be protected from the influence of a cold temperature, by a non-conductor situated on its internal surface. The adipose matter under the skin, may, however, prevent the penetration of cold to the internal parts; and, in fact, corpulent persons appear to suffer less from cold than those with lean, dry frames. In some animals, the fat forms a magazine of nutriment, to which they have recourse during the period of hybernation, being supported during their long winter's sleep by the absorption of their fat. An excessive accumulation of fat is considered as a disease, and is termed *polysarcia*. The developement of this substance is influenced by a variety of circumstances, as age, manner of life, diet, &c. In general, it increases after middle age, particularly in persons of sedentary habits, and those who use a full diet. The abdomen becomes prominent, the buttocks enlarged in size, and the female mammæ become more voluminous. Castration in the inferior animals, and in man, increases the disposition to the formation of this substance.

4. *Medullary*. The cavities of the long bones, and the cells of the spongy ones, are lined by membranes, called the internal periosteum. They are the seats of an exhalation of an oily fluid, called the marrow, which fills the cavities and interstices of the bones, and which resembles the fat, adipose matter of the cellular system. The uses of it are not well known; but by some it is considered as a mere deposit of superfluous, nutritious matter.

Haller and Blumenbach were of opinion, that its use was to render the bones more flexible. In persons who die of chronic diseases, in a state of extreme emaciation, the cavities of the bones, it is said, are found completely empty.

5. *Exhalation of the interior of the eye.* The eyeball is formed of membranes, which inclose several humours. These humours are the product of an exhalation, of which the membranes are the seats.

The humours of the eye are the *aqueous*, secreted by a fine membrane which lines the two chambers of the eye; the *crystalline*, secreted by the crystalline membrane, which is a closed sac, of a lenticular form; the *vitreous*, which is exhaled by a membrane of extreme delicacy and transparency, and of a cellular structure, called the *hyaloid* membrane; the black matter of the choroides; and that which lines the posterior face of the iris, both secreted by the choroides.

The first of these, or the aqueous humour, is a perfectly limpid fluid, consisting of a large proportion of water, of albumen, and some salts. It fills the two chambers of the eye, and if evacuated is speedily renewed, as for example, after the operation for cataract by extraction.

The crystalline humour is a dense, gelatinous body, of exquisite transparency, having the form of a double convex lens. Its central parts are denser than those near the surface. It is contained in a thin capsule, and is composed of water, albumen, and gelatin. It differs from the aqueous humour, in containing a larger proportion of the two latter animal principles.

The vitreous humour is a fluid composed of albumen, gelatin, and several salts, dissolved in a large proportion of water. It is secreted by a very delicate membrane, called the *hyaloid*, in the cells of which it is contained. A morbid increase of it, constitutes the disease termed hydrophthalmia, or dropsy of the eye. The *pigmentum nigrum*, or black matter of the choroides and posterior part of the iris, is secreted by the choroid membrane. It is composed of water, gelatin, several salts, and a peculiar colouring matter.

The aqueous and vitreous humours are renewed with rapidity, when evacuated by accident, or in operations on the eye; and, according to the experiments of Leroy d'Etiole and Coiteau, it appears that the crystalline, when extracted from the eye, is reproduced by exhalation.*

Follicular Secretions.

The follicular secretions are those which are effected by the small secretory sacs, which have already been described under

* Magendie.

the name of follicles, or crypts. These bodies are found only in the mucous membrane and the skin, on the free surfaces of which they open. The viscid, or unctuous fluid, which they secrete, is designed to lubricate these membranes, and to enable them to support, without inconvenience, the habitual contact of foreign bodies, to which, as organs of relation, the skin and mucous membranes are exposed.

1. *Mucous follicular secretions.* The mucous follicles are found in all the mucous membranes, sometimes isolated from one another, and sometimes aggregated together in clusters. The first class, or the simple follicles, are dispersed over the palate, tongue, trachea, œsophagus, stomach, and intestinal canal. They are also found in the mucous membrane which lines the biliary and cystic ducts, in the ureters and bladder, and in the mucous membrane of the vagina. The conglomerated mucous follicles, are the tonsils, Peyerian glands of the intestinal canal, the prostate gland, and the gland of Cowper.

The fluid secreted by the follicles is termed mucus. It is a viscid, colourless, transparent, and insipid fluid, heavier than water, soluble in the acids, insoluble in alcohol, not coagulable like albumen, precipitated by acetate of lead, and becoming, by desiccation in the air, a semi-transparent, brittle solid, of a yellowish colour. It is very similar, in its properties, to vegetable mucilage, but differs from it in containing azote. Bostock and Vauquelin consider it as a proximate principle; but Berzelius thinks that it is composed of lactate of soda, combined with an animal matter. A morbid increase of this secretion in the nasal passages constitutes the affection termed coryza; in the lungs, bronchial catarrh; in the intestines, diarrhœa or dysentery; in the urinary passages, blennorrhagia, &c.

2. *Cutaneous follicular secretion.* The follicular secretion of the skin is effected by little hollow bodies, with membranous walls, dispersed throughout the skin, and termed *sebaceous follicles.* These bodies bear a close resemblance to the crypts of the mucous membranes; but they are never clustered together, as the latter are in certain situations. They exist at the roots of the hairs, and generally the hairs traverse the cavities of the follicles on their way to the surface of the skin. The fluid secreted by them is a thick, unctuous matter, which, diffused over the epidermis and the hair, serves to lubricate and soften them, to defend the skin from the effects of friction, and perhaps to protect it from the influence of moisture.

The number of the sebaceous follicles dispersed over the skin is immense. Mr. Chevalier counted one hundred and forty in the space of a quarter of an inch, which would amount to one hundred and twenty millions over the whole surface of the body. The matter secreted by these follicles is the vehicle of the pecu-

liar animal odour which emanates from certain individuals, forming an atmosphere round them, into which it is so disagreeable for others to enter.

The *meibomian glands*, or *ciliary* follicles, belong to the class of the sebaceous follicles. These are small granular bodies, situated in the thickness of the tarsal cartilages, and secrete a peculiar sebaceous matter, which lubricates the margins of the eyelids, and prevents the irritation which their motions might otherwise produce. It may perhaps also prevent the escape of tears from between the eyelids.

The *ceruminous glands* of the ear also belong to the same class. They are situated in the external auditory passage, and secrete a yellow, bitter, unctuous matter, of a semi-fluid consistence, called the cerumen of the ear. The uses of it are to sheathe and protect the walls of this passage. It sometimes becomes hard and dry, by the absorption of its thinner parts, and then is a common cause of deafness, which, however, is easily relieved by carefully removing the hardened matter.

Glandular Secretions.

Several of these have been considered already. Those which remain to be noticed, are the *salivary*, the *lacteal*, and the *urinary;* or the secretions of saliva, of milk, and of the urine.

1. *Salivary secretion.* The salivary glands are six in number, viz. the two *parotid*, situated in front of the ears, in the hollow between the mastoid process of the temporal bone and the branch of the lower jaw. These glands are composed of granulations, united into lobules and lobes by cellular membrane. Their arteries are furnished by the carotid, the facial, and the temporal. The granulations of which they are composed give origin to excretory ducts, which, by their union, form the *stenonian* duct, which passes across the masseter muscle, perforates the buccinator, and opens into the mouth opposite to the middle molar tooth of the upper jaw. The portio dura, traverses the substance of this gland.

The two *submaxillary glands*. These are situated on the inner side of the ramus of the lower jaw, between the two portions of the digastric muscle. Their ducts are termed the ducts of Wharton, and open at the sides of the frenum linguæ.

The nerves of these glands are derived from the gustatory, by means of which their functions are closely connected with impressions on the organ of taste.

The two *sublingual glands* are situated under the anterior part of the tongue. They are smaller than the submaxillary glands, and their excretory ducts, which are several in number, open

upon the sides of the frenum linguæ. These glands, like the submaxillary, derive their nerves from the gustatory.

The fluid secreted by these glands is termed the saliva. It is constantly flowing into the mouth, and mingles with the fluids secreted by the membrane which lines this cavity, and by the mucous follicle. It is composed of

Water,	992.9
Peculiar animal matter called ptyaline,	2.9
Mucus,	1.4
Hydrochlorate of potash and soda,	1.7
Lactate of soda, and animal matter,	0.9
Free soda,	0.2
	1000.0

According to Mitscherlich, the saliva is most generally a little acid, sometimes neutral, and at other times strongly alkaline. It is acid between meals. During mastication it is alkaline, and sometimes its acidity disappears at the very first mouthful of food. Its acidity is owing to the presence of the hydrochloric, phosphoric, sulphuric, and lactic acids.

The concretions formed on the teeth, commonly called tartar, are supposed to be deposited by the saliva, as this matter is found in the greatest abundance near the openings of the salivary ducts. It is composed of phosphate of lime, of mucus, and some animal matter.

According to Haller, from six to eight ounces of saliva are secreted during a meal. The whole quantity secreted in twenty-four hours has been estimated at about twelve ounces. The secretion is constantly going on, but is much more active sometimes than at others. During sleep very little is secreted. But in eating, particularly during mastication, and in speaking, the secretion is much increased. Acids, spices, stimulants, high-seasoned aliments, all promote the secretion of the saliva. The sight, and even the idea of savoury food, frequently produces the same effect. Sometimes, under these excitations, the saliva is projected in a jet into the mouth. The action of sialagogues, especially the mercurial preparations, excites a morbid increase of this secretion, termed salivation, or ptyalism, in which the quantity of this fluid secreted is sometimes enormous. It has in some instances amounted to twenty-three pounds in a day. In hydrophobia this secretion is so much perverted, that the saliva, if introduced into the blood-vessels, becomes a most dreadful poison. Under the influence of terror or rage, also, it sometimes acquires venomous properties, causing gangrene in the part bitten by the frightened or enraged individual or animal; and sometimes exciting a fatal affection of the nervous system, analogous to hydrophobia.

Secretion of Milk.

The organs which secrete the milk, are the *mammæ*, or breasts. These are two glands, situated on the anterior part of the thorax, below the clavicles, and before the great pectoral muscle, of a hemispherical form, covered by a smooth, delicate skin, and composed of an assemblage of lobes, each of which is formed of several lobules, and these of acini, or granulations. The lobes are connected together by a dense cellular tissue, and are buried in a dense mass of fat. These acini appear to consist of minute vesicles, and an organized tissue, and they give origin to the radicles of the lactiferous ducts, which, gradually uniting, form larger trunks, corresponding in number with the lobes, and amounting to about fifteen in each breast. These trunks do not anastomose with one another, but converge towards the centre of the gland, where they terminate in delicate excretory canals, which are collected into a bundle, and enveloped in a kind of erectile sheath. This constitutes the nipple, the small body which projects from the centre of the mamma, surrounded by a pink-coloured or reddish-brown areola. The nipple, which is of the same colour, presents on its surface numerous fine papillæ, in which are the orifices of the lactiferous ducts. The skin of the areola and nipple contains a number of sebaceous glands, which secrete an unctuous matter, designed to screen these parts from the saliva of the child.

The arteries of the mammæ are derived from the internal mammary, the axillary, the first intercostals, and the thoracic; its nerves, from the brachial plexus and the intercostals. These glands are abundantly supplied with lymphatics.

The product of the secretion of the mammæ, the milk, is a fluid of a well known colour and taste; and, according to Berzelius, is composed of milk, properly so called, and cream. The milk consists of the following principles, viz.—

Water,	928.75
Cheese, with a trace of sugar,	28.00
Sugar of milk,	35.00
Hydrochlorate of potash,	1.70
Phosphate do.	0.25
Lactic acid, acetate of potash, and lactate of iron,	6.00
Phosphate of lime,	0.30
	1000.00

Cream is composed of

Butter,	4.5
Cheese,	3.5
Whey,	92.0
	100.0

Whey contains 4.4 of sugar of milk and salts.

Human milk differs from that of the cow in containing less caseum, and a much larger proportion of sugar of milk. The qualities of the milk are much influenced by the nature and quantity of the aliments. Under a diet of animal food, it is more abundant, of a thicker consistence, and less acid; while a vegetable diet diminishes the quantity of this secretion, and renders it thinner and more acid. The quantity of this secretion depends also very much upon that of the ingesta. A woman who consumes five or six pounds of solid and liquid aliment within twenty-four hours, will furnish in the same period from two to three pounds of milk, or even more. The increase of the secretion occurs too soon after taking food to allow time for the digestion of the latter and its conversion into blood, or even chyle. It easily acquires the flavour and the peculiar properties of substances taken into the stomach, either as food or medicine. Hence, the disagreeable flavour which cow's milk frequently acquires, when this animal has fed upon certain kinds of plants. In like manner purgative substances, as salts or rhubarb, taken by the nurse, frequently operate upon the bowels of the infant. Its qualities, also, are sometimes affected by mental emotions. It has been a subject of controversy whether the milk is secreted from the blood or from the chyle; or, as some physiologists have supposed, from the lymph. The question seems to be decided by the analogy of the other secretions, as well as by the fact that mercurial injections, thrown into the mammary arteries, readily pass into the lactiferous ducts, and *vice versâ*. Another fact, which seems to be conclusive of the question is, that blood is sometimes drawn into the lactiferous ducts, when the infant has completely drained the breast of milk, and yet continues to suck with force.*

Before the age of puberty the mammæ are imperfectly developed, being small and flat; but at puberty, when the catamenia appear, they enlarge and become prominent. Until the period of fecundation, however, they remain inactive; but as soon as pregnancy has taken place they begin to swell, and become affected with pricking and shooting pains. Towards the close of utero-gestation, they secrete a serous fluid, which is termed *colostrum*, and the secretion sometimes retains the same character two or three days after parturition. The secretion of the milk continues until the end of the period of nursing, and ceases in the course of the second year. In some rare examples milk has been secreted by the mammæ of young virgins, and even of men.

* Vesalius states that he has seen the mammary veins in a nurse full of milk.

Secretion of Urine.

The glands which secrete the urine are the kidneys. These are two bodies, four or five inches long, and two or three in breadth, in shape resembling the kidney-bean. They are situated on the sides of the vertebral column, before the *psoæ* and *quadrati lumborum* muscles, opposite the two last dorsal and the two first lumbar vertebræ, imbedded in fat. The right kidney lies at the under and back part of the large lobe of the liver; the left is situated under the posterior part of the spleen, and behind the left part of the stomach, pancreas, and colon. Sometimes one kidney is wanting, and in some instances there are three. They are covered on their anterior part by the peritoneum, reflected from the liver and the spleen.

These glands are composed of two distinct substances, an external, termed the *cortical*, and an internal, called the *tubular*. The cortical substance is about two lines in thickness, is of a lighter red and softer consistence than the tubular, and consists almost entirely of blood-vessels and [acini] *granulations*, which are the commencements of the *tubuli uriniferi*. It is supposed to constitute the secretory part of the gland.

The tubular part consists of a number of conical bodies, varying from seven to twenty, with their bases directed towards the circumference, and their summits towards the centre, or pelvis, of the kidneys. The tubular part is of a darker colour, and firmer consistence than the cortical. It is composed almost wholly of convergent, uriniferous canals, which originate in the cortical substance, and which terminate in small apertures at the summits of the cones. The orifices of the uriniferous canals are less numerous than the canals themselves. The rounded summits of the cones, which are perforated with the orifices of the uriniferous ducts, are termed the mamillary processes. Each of these is enclosed in a loose conical sac, termed an *infundibulum*.

The pelvis of the kidney is a membranous sac formed by the union of the infundibula. At its inferior part it contracts, and is continued into the *ureter* or excretory duct of the kidney. The ureters are long, membranous canals, about the size of a writing-quill, lined like the pelvis of the kidney with mucous membrane, very dilatable, and opening into the inferior and posterior surface of the bladder.

The kidneys receive their blood by the renal or emulgent arteries, two large vessels which spring immediately from the aorta. No other organs in the body, in proportion to their volume, receive so large a quantity of blood. A free communication exists between the renal arteries and the veins, and the tubular part of the kidneys. Injections thrown into the renal

artery pass into the veins and into the cortical substance, and thence into the pelvis of the gland.

The renal nerves are derived from the great sympathetic.

The urinary bladder, into which the ureters open, and convey the urine from the kidneys, is a membranous sac, situated in the cavity of the pelvis, between the pubis and the rectum. In females, it lies between the pubis and the uterus. Its posterior and upper surface is covered by the peritoneum, and is in contact with the inferior part of the small intestines.

The bladder is composed of four tunics, viz. a serous, cellular, muscular, and mucous. The serous, derived from the peritoneum, invests only the superior part of the bladder. The cellular is situated immediately beneath the peritoneal, but is much more extensive, as it completely encircles the bladder. It is very loose, and loaded with adipose matter.

The muscular coat consists of muscular fibres which run in various directions over the bladder, and, by their contraction, diminish the capacity of this reservoir, and effect the evacuation of its contents. The inner coat is a mucous membrane, which is continuous with that which lines the ureters.

The bladder has three apertures, two of them being the orifices of the ureters, and the third, the mouth of the bladder, or, the commencement of the *urethra*. This last is a canal, twelve or fifteen lines long in females, and opening between the *clitoris* and the *vagina;* but in males it is eight or nine inches in length, extending from the mouth of the bladder to the *glans penis*. It is formed of a long fibrous membrane, lined on its interior by a mucous coat. The nerves of the bladder are derived from the hypogastric plexus.

The posterior extremity of the urethra is surrounded in three-fourths of its circumference by a collection of mucous follicles, commonly called the *prostate gland*. Before the prostate gland there are two small glandular bodies, about the size of a pea, which open into the urethra, and which are termed *Cowper's glands*. These, together with the prostate, secrete a mucus which passes into the urethra.

In a case mentioned by Lieutaud, the urinary bladder did not exist. The ureters, which were as large as the small intestine, opened directly into the urethra.

Secretion. If an incision be made into the pelvis of the kidney of a living animal, the urine may be seen to exude slowly from the summits of the excretory cones. It passes thence into the pelvis, from which it enters the ureters, and from these canals it distils slowly into the bladder, gradually filling and distending this reservoir. If the uriniferous cones be slightly compressed, a considerable quantity of urine is forced out, which, however, is not limpid like the natural secretion, but thick and turbid.

The passage of the urine from the ureter into the bladder, according to Magendie, is not continual. But at short and regular intervals, the ureters, distended by the urine, open their lower orifices and suffer the fluid to enter the bladder. The ureters then collapse and their orifices close, and the passage of the urine into the bladder ceases for several seconds, and then recommences in the same manner as before. In general, the passage of the urine into the bladder coincides with the act of inspiration.

The urine accumulated in the bladder, cannot ascend into the ureters, for these tubes open obliquely into the bladder, so that the pressure of the fluid which distends it, tends to close the orifices of the ureters, and to prevent any reflux of the urine towards the kidneys. That it does not continually escape from the urethra, according to Magendie, is owing to several causes; as, the disposition of the urethra, particularly towards its vesical extremity, to maintain a contracted state; a tendency which depends on the circumstance, that the membranous part of the urethra is composed exteriorly of muscular fibres which are endued with a strong contractile power.

But the principal cause Magendie states to be the action of the muscles which elevates the anus, including the *compressor urethræ* of Wilson, which, by this contraction, press the urethra upwards, keeping its parietes forcibly in contact, and thus closing its posterior orifice.

When the bladder has become distended with urine, to a certain degree, a peculiar sensation is excited in the organ, with a desire to evacuate it. The bladder is susceptible of great distention. In its natural state it is capable of containing about two pounds of urine; but it sometimes becomes so much distended that its fundus extends up above the umbilicus, and more than two gallons of urine have been found in it. The excretion of the urine is accomplished by the contractile power of the bladder, assisted by the action of the abdominal muscles. The habitual disposition of the muscular coats of the bladder to contract, is resisted by the external extremity of the urethra. But under the influence of the sensation which solicits the evacuation of the urine, the voluntary power excites the abdominal muscles to contract, and the action of these muscles assists the contraction of the bladder in overcoming the resistance. The will also relaxes the muscles which elevate the anus, and which, by this contraction, close the urethra. As soon as the resistance of this canal is overcome, the urine is evacuated by the contraction of the bladder, which is generally aided by the abdominal muscles, in which case the fluid is evacuated with a much more vehement jet. We can instantly arrest the discharge by the voluntary contraction of the *levators* of the anus. The excretion

is partly a voluntary, partly an involuntary act. The contraction of the bladder is involuntary; that of the abdominal muscles is dependent on the will. The contraction of the bladder, however, is sufficient to expel the urine; for in experiments in which the abdomen in living animals has been opened, and the bladder removed from the action of the abdominal muscles, and even when the bladder with the prostate, and a small portion of the membranous part of the urethra, has been detached from the animal, the urine has been discharged by the action of the bladder alone. The small quantity of urine which remains in the urethra after the bladder has ceased to contract, is expelled by the contraction of the perineal muscles, particularly of the *bulbo-cavernosus.*

The product of the secretion of the kidneys, the *urine,* is a fluid of a yellowish colour, of a peculiar, sometimes ammoniacal odour, and an acrid bitter taste. Its specific gravity is variable, being in the ratio of from one thousand and five to one thousand thirty-three, to that of water. When recent, it reddens the vegetable blue colours, but in the act of decomposing it changes them to a green. The first of these properties is attributed, by different chemists, to the presence of various acids. Vauquelin ascribes it to the phosphoric, Thenard to the acetic, Berzelius to the lactic, Scheele to the benzoic, particularly in infants; Prout to the superlithate and superphosphate of ammonia. Its powers of converting blue colours to a green, is owing to the developement of ammonia, during the decomposition of the urine. The composition of urine, according to Berzelius, is as follows, viz.

Water,	933.00
Urea,	30.00
Uric acid,	1.00
Lactic do., lactate of ammonia, and animal matter combined with them,	17.14
Mucus of the bladder,	0.32
Sulphate of potash,	3.71
Sulphate of soda,	3.16
Phosphate of soda,	2.94
Hydrochlorate of soda,	4.45
Phosphate of ammonia,	1.65
Hydrochlorate of ammonia,	1.50
Earthy matter, with a trace of fluate of lime,	1.00
Silex,	0.03
	1000.00

The principal properties of the urine are owing to the *urea,* a peculiar animal matter, which contains a large proportion of azote, and is strongly disposed to putrefaction. By the decomposition of the urea and of the mucus, ammonia is formed, which gives to decomposing urine its alkaline properties. The acid properties of recent urine depend on the presence of the free

acids, which enter into its composition. One of these, the *uric*, is frequently deposited, in the form of a reddish matter, on the sides of the vessels into which the fluid is received. This acid, also, frequently gives rise to sabulous or calculous concretions.

The composition and the physical properties of the urine are subject to great varieties. Under the free use of watery drinks, its quantity increases, and it becomes paler and more diluted.* The proportion of uric acid increases under a full animal diet, accompanied with sedentary or inactive habits of life. The same acid diminishes in quantity, and sometimes wholly disappears, under a diet of vegetable matter, or of substances which contain no azote, as sugar, gum, butter, oil, &c. According to Chevreuil and Magendie, the urine in dogs may be rendered at pleasure either acid or alkaline, by confining these animals to a diet exclusively animal or vegetable. Certain colouring substances, taken into the stomach, as rhubarb and madder, communicate a deep yellow or red tinge to the urine. The same effect is produced by immersion in a bath, formed by an infusion of these substances. The urine also frequently becomes impregnated with the odour of certain substances which have been eaten or swallowed, particularly asparagus and the turpentines.

Many substances, either introduced into the stomach, or injected into the veins, find their way to the kidneys, and may be detected in the urine. If a few grains of the nitrate or prussiate of potash, for example, be taken into the stomach, the presence of the salt may be discovered in the urine a short time after; but what was worthy of remark, not a trace of it can be detected in the blood. Magendie also ascertained that when the prussiate of potash was injected into the veins, or was absorbed either from the intestinal canal, or from a serous membrane, it soon found its way into the urine, where its presence might be readily detected. If the quantity of the salt injected were considerable, its presence in the blood might be ascertained by the proper chemical tests; but if very little were injected, it was found impossible to detect it in the blood by the usual means. The same results were obtained when the prussiate was mixed with blood drawn from the veins; while the presence of the salt could always be detected in the urine, in whatever proportion it existed in this fluid. It appears, therefore, that substances may exist in the blood, on their route to the kidneys, without the possibility of our detecting them in this fluid; while their presence in the urine, as soon as they reach this secretion, may be readily discovered by ordinary chemical means.

The extirpation of one of the kidneys in dogs, according to Magendie, does not affect the health of the animal, but the loss

* The average quantity secreted daily is estimated at three or four pounds.

of both is inevitably fatal in a few days, varying from two to five. The same physiologist remarks, that in these cases there is an extraordinary increase of the secretion of bile, the stomach and intestines of the animal becoming filled with the fluid.

A curious fact, relating to the excision of the kidneys, which has already been mentioned, is, that after the extirpation of these glands, a considerable quantity of urea can be detected in the blood, though not a trace of it can be found in the fluid before the experiment. Prevost and Dumas estimate the quantity of urea which a healthy dog habitually produces, at a drachm in twenty-four hours. After the excision of the kidneys five ounces of the blood of the animal were found to contain one scruple of this substance. The probability seems to be, that the urea pre-exists in the blood, and is merely separated by the kidneys; but that after the extirpation of these organs, as its elimination from the blood is prevented, it accumulates in this fluid, until it amounts to a quantity which may be recognised by chemical analysis. The introduction of urea into the blood has been found to produce an increase of the secretion of urine.

Uses of the Urinary Secretion.

The secretion of the urine differs, in one respect, from all the other secretions, viz. that it is not designed for any local use. It is subservient to two general purposes, viz. the depuration of the blood, and the decomposition of the body; and in this twofold respect, it is one of the functions most necessary to life. Some idea of the importance of this function may be formed from the calculation that ten thousand ounces, or nearly eighty gallons of blood are brought to the kidneys every hour by the renal arteries.

Many foreign substances are constantly entering the mass of the blood, which alter the qualities of this fluid, from which it is necessary it should be regularly purified. The digestive and respiratory organs, and the great surface of the skin, are the three avenues by which extraneous substances may enter the blood. Further, many of the secreted fluids, even the excrementitious, if any obstacle prevent their excretion, are reabsorbed and carried back into the circulation. This is the case with the bile, and milk, and probably with all the others. Even pus, the fluid of dropsies, and other morbid products, and even fæcal matter, are sometimes absorbed, and enter the mass of the blood. Now the secretion of urine is the means appointed by nature to purify the blood from these and other foreign substances. Accordingly, we find the urine saffron-coloured in jaundice, in consequence of the admixture of bile, and of a red or deep yellow colour, after the ingestion of madder or rhubarb. Many foreign

substances, also, which are taken into the stomach, but are incapable of chylification, soon find their way to the kidneys, and are secreted with the urine; and the celerity with which some of them find their way from the stomach or the blood-vessels into this secretion is truly remarkable. Home discovered that rhubarb could be detected in the urine seventeen minutes after it had been swallowed. And Fodéra, having injected a solution of hydrocyanated ferruret of potash into the stomach of an animal, found that the urine gave indications of the presence of the salt in five or six minutes. He then killed the animal, and upon examining the blood discovered the salt in this fluid also.

In another experiment, in which the hydrocyanated ferruret of potash was injected into the jugular vein of a horse, the kidneys gave decided indications of its presence in the course of one minute. The superfluous part of our drinks follows the same route, and is thus discharged from the system. Foreign substances, absorbed in respiration, are in many instances discharged by the same channel. Thus the urine of a person who breathes an atmosphere impregnated with the vapour of *ol. terebinth*, acquires a peculiar odour, which has been compared to that of violets. From the fact that the urine is the vehicle by which these foreign matters are removed from the blood, and is in part composed of these impurities of the vital fluid, it has sometimes been aptly termed *fæces sanguinis.*

Further, it is well known that part of the materials which compose the solid structure of the body are regularly taken up by internal absorption and carried into the circulation; and this process is as incessant as nutrition, the parts removed by absorption making room for the fresh materials to be deposited by the nutrient vessels. Our organs are decomposed as fast as they are recomposed or nourished, and of this decomposition the renal secretion is an essential instrument. The peculiar principle, *urea*, contained in the urine, has been supposed to be derived from the old elements of nutrition, combined together in a peculiar mode in the blood-vessels, or by the vital power of the kidneys.

Of the two offices of the renal secretion which have been mentioned, the depuration of the blood, and the removal of the decomposed matter of nutrition, the first seems to be executed by a kind of filtration; for it is found that, under certain circumstances, foreign matters are sometimes separated from the blood by other strainers. Thus, the fluid of dropsies sometimes manifests the qualities of the aliments which have been taken, and sometimes the presence of bile; facts which evince that the secretory structure of the kidneys is not essential to the separation of these substances, and that they may be secreted by a simpler apparatus. So the bones become coloured red after the use of aliments containing madder; the colouring matter, instead of being secreted

from the blood by the kidneys, being deposited in the bones with the matter of nutrition. The kidneys, however, are the organs which are particularly charged with the office of removing foreign substances from the blood; and are to the drinks what defecation is to the solid *aliments.*

It is worthy of remark, that, after the old matter of nutrition is taken up by interstitial absorption, and conveyed into the blood, this fluid is subjected to the influence of respiration, *before* it is carried to the kidneys; and *after* being purified by respiration, and converted into arterial blood, it is transmitted to the kidneys, to be further purified, by the separation of the principles of the urine. It is a curious circumstance, that the kidneys, though depurating organs, operate upon *arterial blood,* which has shortly before been purified in the lungs; and this blood, when purified by the separation of the foreign matters which may have been introduced into it, as well as of the old elements of nutrition, furnished by the *detritus* of the organs, becomes *venous blood,* which must again be subjected to the action of the lungs, before it can be employed for any other purposes in the animal economy. The blood, as it issues from the lungs, is perfectly adapted to the uses of the system; for we find that it is immediately transmitted to all the organs, to furnish the elements of nutrition, and of the secretions, and the necessary vital excitement. Yet we find that one-eighth of this blood is diverted into a particular channel, by which it passes to the kidneys, where it parts with certain principles which are noxious to it, and if retained in the blood, are inevitably fatal in a short time. It is not very apparent why this particular portion of the arterial blood only should be subjected to the action of the kidneys, while all the remaining, and vastly the larger part, though equally impregnated with these noxious principles, is transmitted, without this depuration, to all parts of the body. Nor is it more apparent, why, after undergoing this purification in the kidneys, and parting with these noxious ingredients, it is rendered more unfit than it was before to administer to the wants of the economy, in being converted into venous blood, and again requiring the action of the lungs to prepare it to subserve the uses of the system.

CHAPTER XIX.

NUTRITION.

The nutritive functions, which have so far been considered, have all one and the same aim, viz. that of preparing materials, which may become incorporated with the living system, and

repair the losses which it is constantly sustaining, from exercise of the functions of life. Digestion, absorption, respiration, circulation, and the secretions, are only preliminary functions, subservient to *nutrition*, which may be regarded as the consummation of the assimilating functions.

That the fabric of the body is undergoing a perpetual decomposition and renovation, cannot be doubted. The immense losses which the system is constantly sustaining from the numerous secretions and excretions, particularly from the renal and cutaneous, the first of which contains a very large quantity of animal matter, derived in all probability from the *débris*, or rubbish, of the decomposing organs;—the necessity of frequent and ample supplies of aliment, and the extreme emaciation which is the consequence of a few days' abstraction from it; the changes of volume, which the organs and the whole body undergo, in passing through the successive periods of life, which can only be accounted for, on the supposition of an entire remoulding of the whole, from time to time, by the nutritive powers;—these, and many other considerations, leave no reasonable doubt, that the process of decomposition is perpetually going on, taking to pieces the solid fabric of the body, and that the work of nutrition follows close upon its footsteps, in repairing the losses which are thus made. A well-known experiment with madder, has usually been considered as decisive of the point, that there is a perpetual decomposition of animal matter. If this substance be mixed with the food of animals, it is found that in a short time the bones of the animals become of a red colour; and if the madder be then withdrawn from their food, the red colour in a short time wholly disappears, evidently from the absorption of the madder, which had been previously deposited in the bones. From this experiment, it has been inferred, that even the hard substance of the bones, during life, undergoes continual decomposition, and of course, that the losses which they sustain must be repaired by the deposition of new ossific matter; and if this be true, the soft solids which have less cohesion, must probably undergo a more rapid decomposition. This experiment, however, in strict logic, proves nothing more than that the colouring matter of madder is deposited on the bones, if the substance be taken a certain time with the food; and that this colouring matter is afterwards absorbed and carried out of the system. It proves, in fact, nothing more than the deposition and absorption of madder itself, and not that of the bones, or the other animal textures; and as madder is not an alimentary substance, and is incapable of perfect assimilation, (for otherwise it would not communicate its colour to the bones,) no inference can logically be made, from the fact of its absorption, to the absorption of the assimilated matter of which the living solids are actually composed.

Many facts have led some physiologists to the opinion, that while many, if not most of the solids are subject to this perpetual change of matter, there are some which, when once formed and fully developed, remain unalterably the same. Blumenbach is of opinion, that only those solids undergo this successive change, which possess the *reproductive* power, i. e. the property which certain parts of the bones, and nails,* and epidermis possess of repairing, not only the natural losses of matter, from the wear and tear of life, but even the removal of considerable portions of their substances from external injuries. While in those parts whose vital powers are of a higher order, the parenchyma which forms their base appears to be permanent, and is liable only to this change, viz. that the interstices of the tissue, while nutrition is active, are constantly full of nutrient animal gelatine; but when nutrition languishes, they are deprived of their gelatine, collapse, and become extenuated. This view would confine the change of matter in the body, to the parts endued with the lowest degrees of vitality, as the bones, nails, and epidermis. That the *cutis vera* is not really reproduced, and of course must be a stranger to this change of matter, Blumenbach remarks, is probable from the fact that scars are frequently permanent, and that the marks imprinted upon the skin in the operation of tattooing, in which charcoal, ashes, soot, the juices of plants, &c. are pricked in by a pointed instrument, remain ever afterwards.

Bourdon infers from these facts, that there exists in the organs a fundamental tissue which undergoes no change.

Other physiologists are of opinion that all parts of the body, without exception, are incessantly undergoing a renovation of their substance, by an uninterrupted movement of nutrition. The volume, the consistency, the composition, the configuration, the texture of the body, and of all its parts, the cellular tissue, membranes, vessels, nerves, muscles, cartilages, bones, tendons, ligaments, &c. all are supposed to be subject to incessant changes, more or less rapid. All animals, Tiedemann observes, live in an uninterrupted circle of formation and of transformation, of destruction and of renovation. This, in all probability, is the true doctrine. There is beyond all question a constant waste of the elements of the organization by the operations of life. Every function in its exercise occasions a consumption both of materials and of power; and not a single action of life, however inconsiderable, but demands the presence, and occasions the expenditure of blood. Not a fibre contracts, not a sensitive filament experiences an impression, without undergoing some change in its own organic condition, some deterioration of the perfection of its vital

* According to Blumenbach, the nails, after the loss of the first phalanx of the finger, have been known to be reproduced on the middle phalanx.

mechanism. Not a single ray of light falls upon the eye, not a transient thought or momentary feeling flits through the brain, but it carries away with it some element of power, leaving the exquisite organization of the part in a lower degree of vital endowment. No part therefore that is not condemned to a state of absolute inaction in the system, can be exempted from the necessity of constant reparation; and no such part is known, or can be supposed to exist.

To supply the great waste occasioned by the numerous and complicated actions of the living system, there is a constant influx of crude materials and power from the physical world into the vortex of life. Here these elements, by a higher or transcendental chemistry, are converted into that mysterious fluid the blood, in which are stored up all the elements both of structure and of power, employed in the formation of the diversified organs of the body.

Now every part of the system is supplied either with red or colourless blood by receiving vessels, and sends back the residue charged with the *débris* of its own nutrition, by corresponding returning vessels. The returning fluid differs from that which the organ received. Its properties are altered, and its constituent parts are no longer the same. It has lost a portion of its vitality, and it must be sent to the lungs to be *made over again,* before it can be employed anew in nourishing the organs. Now it is impossible to account for this change in the blood, except in the secretory organs, but on the supposition that some of its principles are expended in the repair of the organs, and that their place is supplied by the matter superseded, or the rubbish of nutrition.

It will appear, from what has been said above, that the energy of nutrition, in every organ, must keep pace with the activity of its functions. According to Tiedemann, the rapidity of this renovation of matter in the solid parts of animals is in the direct ratio to the degree of complication of their structure, and the variety of their vital manifestations. Animals require larger and more frequent supplies of food, in proportion to the greater complexity of their organization, and the diversity and energy of the vital operations. The rapidity of this change of matter in the organism, is also intimately connected with the nature and number of the external impressions to which animals are exposed. Heat, air, light, sound, electricity, food, odours, mechanical impressions, &c. act as stimulants to animals exposed to their influence, increase the energy of their vital manifestations, and occasion a more rapid exchange of the materials of their organization. The rapidity of this change, in different classes of animals, is also proportioned to the degree of developement of

the system of animal life, as the nervous system, the organs of sense, and those of voluntary motion.

With respect to the agents of nutrition, it is evident they can be none but the organs themselves. The function of nutrition has no separate organ, like the various secretions, and the absorbent system, to which it may be considered as opposed. Every tissue, and every organ, is the immediate instrument of its own nutrition. The materials of nutrition are contained in the blood. When this fluid, replenished with animalized matter, and depurated by the lungs and the kidneys, is brought in the course of the circulation to the interior of the various organs, the nutrient capillary vessels select and secrete those principles of the blood which are analogous to those of which the organs are severally composed, and suffer the heterogeneous principles to pass on. Thus the nutrient vessels of the bones secrete phosphate of lime; those of the brain the albumen of the blood, and the other elements of nervous matter; those of the muscles the fibrin; &c. Every tissue imbibes, and, by a peculiar vital affinity, identifies with its own texture those principles of the blood which are of the same nature with itself. But by what mechanism the types of the various organs are preserved unaltered, in this perpetual change of the materials of which they are composed, we are wholly ignorant.

It is evident that as fast as the new materials are deposited in the organs, the old must be removed by absorption to make room for them. The physiologists of the mechanical school, supposed that the changes in the organs consisted in the *detrition*, or wearing away of their molecules, by the vital motions. While the modern chemical physiologists believe that there is a kind of *acidification*, or combustion, going on in the living organs, in which the oxygen of the arterial blood combines with the organic elements of the parts. This opinion seems to derive some confirmation from the fact, that many of the excretions contain free acids. Thus, a large quantity of carbonic acid is constantly exhaled by the respiratory organs and the skin; and the urine, which of all the excrementitious fluids is much the most highly charged with the *débris* of the organization, contains several free acids, as the uric, the lactic, and, according to some physiologists, the acetic and the phosphoric. This opinion is embraced, in part, by Tiedemann, who remarks that the nature of the matters removed by excretion, appears to indicate that a peculiar process is executed in the organs, by which the organic combinations of a higher order or more complicated character, are converted into inferior or more simple combinations, and sometimes into inorganic ones. The complicated animal combinations, formed by the powers of assimilation

from the materials received into the system from without, are decomposed by the vital action of the organs, and converted into organic combinations of the lowest class, and sometimes even such as are inorganic ; and this process, Tiedemann supposes to be analogous to combustion. The formation of inorganic acids, in the excreted fluids, has already been noticed. Besides these, may be mentioned certain principles which exist in the bile, as the biliary resin, and cholesterine, two ternary compounds, which may be considered as organic combinations of the lowest class, and which are evacuated by the alimentary canal. The urine also contains organic principles, which may be referred to the same class as the urea, and the uric acid, besides many inorganic compounds, consisting of a great number of different salts. Tiedemann refers to this process the production of animal heat, which, he remarks, is exactly proportioned in animals to the rapidity with which the materials of the organization are renewed.

Some physiologists have supposed that there is only one kind of nutritive matter, and that out of it all the organs are nourished. The different chemical composition of the organs, however, seems to be inconsistent with the unity or identity of the matter of nutrition. How, for example, can the albumen of the brain, the gelatin of the tendons, the fibrin of the muscles, the calcareous phosphate of the bones, the fat of the cellular tissue, be derived from one and the same nutritive matter ? It is enough to suppose that the arterial blood, which is conveyed to every organ, contains in itself all the nutritive principles which are necessary to the renovation of the organs; and that out of this apparently homogeneous fluid, the nutrient vessels of each tissue select, by a peculiar vital affinity, such as are homogeneous to the nature of the tissue, as in the case of the other secretions.

Nutrition seems to be dependent, in some measure, though how far it is difficult to determine, upon the nervous influence. A limb which has become paralytic, by a section, or compression, or any morbid affection of the nerves distributed to it, in some instances preserves its original volume ; a fact which proves that its powers of nutrition are unimpaired by the loss of the nervous influence. More generally, however, it becomes dry and withered, and sensibly diminished in volume; an effect which may perhaps be attributed, in part, to the want of exercise of the paralysed part. A fact mentioned by Magendie appears to prove that nutrition is, to a certain extent, influenced by innervation. He found that when the fifth nerve is divided in the cavity of the cranium of a rabbit, close to its apparent origin, the surface of the eye inflames at its upper part, and the superior segment of the cornea becomes clouded; and if the fifth nerve be destroyed upon the petrous portion of the temporal bone, where its destruc-

tion involves that of the Gasserian ganglion, the whole cornea becomes opaque in twenty-four hours; and the next day the conjunctiva and the iris inflame, the crystalline lens and the vitreous humour begin to lose their transparency, and soon become entirely opaque, and in eight days after the section of the nerve, the cornea detaches itself from the sclerotica, and the humours of the eye are discharged by the aperture. The nutrition of the eye, then, according to Magendie, is evidently subject to the nervous influence.

The division of the *par vagum* in animals also gives rise to inflammation of the stomach, if the operation is not fatal in less than three or four days; a fact which, perhaps, may be referred to the same cause.

CHAPTER XX.

ANIMAL HEAT.

Calorification is a function so intimately connected with nutrition, that it may not improperly be considered in this place.

Before the discovery of the composition of the atmosphere, of the formation of carbonic acid, and of the nature of combustion, the origin of animal heat was a subject on which a good deal of fruitless speculation was lavished; and, as is often the case where reasoning is substituted for experiment and observation, the consequence was a wider departure from truth, than the first crude conceptions of the earliest observers. It is a little curious, that Galen was struck with the analogy between respiration and combustion, since he compares the lungs to the wick of a lamp, though he was not aware of all the points in which the analogy holds. In modern times, previous to the discoveries in pneumatic chemistry, the production of animal heat was ascribed to a variety of insignificant causes, especially attrition, or the friction of the blood against the sides of the vessels. Some physiologists supposed that heat was an essential property of life, that the principal focus of animal heat was the heart, and that the chief office of respiration was to *cool* the blood; an idea well expressed by the phrase, *ventilation of the blood*, adopted by Dr. Good.

The discovery, by Black and others, of the production of car-

* This opinion is confirmed by pathological facts.

bonic acid, both in respiration, and in the combustion of vegetable substances, first brought to light the real analogy which exists between these two processes; and they led Black and his followers to the opinion, that respiration is, in fact, a species of combustion, in which a sufficient quantity of heat is developed in the lungs, to preserve the temperature of the animal, at the requisite elevation above that of the surrounding element. A difficulty which encumbers Black's hypothesis is, that it leaves unexplained the fact, that the temperature of the other parts of the body is as great as that of the lungs; whereas, if these organs are the great focus of animal heat, the place where it is first developed, and whence it is diffused to other parts of the system, their temperature, we should expect, would be much higher than that of other parts of the body. This doctrine, however, was adopted in substance by Lavoisier and his followers.

A very important modification of this opinion was proposed by Crawford, no less remarkable for its ingenuity, than for the happy explanation it furnishes of the difficulty which encumbered the hypothesis of Black and Lavoisier. Crawford assumed, as they had done, that respiration is a species of combustion, in which the air inhaled into the lungs undergoes the same change as by the combustion of substances containing carbon, and that heat is generated in precisely the same manner. But he attempted to establish the fact, that the arterial blood, into which venous blood is converted by respiration, possesses a greater capacity for caloric than venous blood; and that the heat, generated in the lungs by the combination of oxygen and carbon, does not increase the temperature of the lungs, but is immediately absorbed, and becomes latent, in saturating the increased capacity of arterial blood. Hence, though heat is generated by respiration, yet it is not actually disengaged, or rendered sensible in the lungs, but is absorbed, and becomes latent, in the arterial blood, and is gradually developed in the course of the circulation, as the blood loses its arterial, and assumes the venous character; for the venous blood having a less capacity for heat than arterial, i. e. requiring less caloric to preserve it at the same temperature, will have its temperature raised by the gradual developement of the excess, while it is assuming the venous properties.

Unfortunately for this beautiful theory of Crawford, the position which forms the corner-stone of the whole, viz. that arterial blood possesses a much greater capacity for caloric than venous, has been disproved by Dr. John Davy, who maintains from his own experiments, that there is little or no difference between the capacity of arterial or venous blood.

Another theory of animal heat is that of Mr. Brodie, who infers from experiment that the production of animal heat is not a result of respiration, but depends on the nervous influence.

His experiment consisted in decapitating an animal, and keeping up respiration artificially, by inflating the lungs. He found that the usual changes in the blood were effected by this artificial respiration, without the aid of the nervous system; for the venous blood assumed the arterial colour, and carbonic acid was formed exactly as in natural respiration. But notwithstanding the usual changes took place in the blood, and in the air introduced into the lungs, the generation of animal heat was suspended, and the temperature fell with greater rapidity than in another animal killed at the same time, in which artificial respiration was not practised. This experiment, however, is not absolutely conclusive. Dr. Philip discovered that the cooling of the animal was owing to the circumstance, that *too much air* was forced into the lungs. He found, that if a less quantity were introduced, the cooling process was sensibly retarded; and, in one experiment, he succeeded in raising the temperature nearly one degree. At the present day, many physiologists are disposed to transfer from the lungs to the capillary system, the function of generating animal heat. The production of this principle seems to be universally connected with the action of vital forces, and to follow all the vicissitudes by which these are affected. Hence it happens, that heat is always increased by the energetic and prolonged action of any organ whatever, as well as by any morbid excitement; that it is subject to frequent variations, being increased in some parts, and diminished in others. The head becomes hotter in deep thinking, an inflamed part is hotter than the neighbouring parts, a draught of wine excites a feeling of heat in the stomach, &c.; facts which appear to prove that it is in the capillary vessels that the production of animal heat takes place. It is not easy to determine the nature of the vital actions in these vessels, by which caloric is evolved; but it seems not improbable that it is in the changes of combination of the molecules of the fluids and solids of the body, in the processes of nutrition, secretion, digestion, hematosis, &c., that we are to seek for the source of the animal heat disengaged in the capillary vessels. This supposition will account for the variable states of calorification under different circumstances of the system, as the energy of the function is regulated by the degree of activity of nutrition, secretion, &c., which processes are constantly varying in their energy and excitement.

Now, two conditions are necessary to the functions of the capillary vessels, and, consequently, if the last mentioned view be correct, to the production of animal heat; one, the presence of arterial blood; the other, the action of the nervous system. The vital processes, which are executed by the capillary vessels, require the aid of the nervous influence, and the presence of arterial blood. If a part be deprived of arterial blood, or be cut off

from all communication with the great nervous centres, its nutrition languishes, and its temperature falls. Two conditions also are necessary to the presence of arterial-blood in a part as well as in the whole system; one is the function of respiration, to form it; the other the circulation, to distribute it. Hence it follows, that three conditions are favourable to the production of animal heat; a respiratory apparatus, a developed circulating system, and the nervous influence, co-operating together in producing energetic vital actions. Calorification is not dependent on either exclusively, but is the result of the whole.

Of these three functions, however, respiration seems to claim the largest share in the production of animal heat. The connexion of calorification with this function cannot be mistaken. Every thing which increases the activity of respiration, the consumption of oxygen, and the production of carbonic acid, as animal food, wine, and exercise, increases the heat of the body. Whenever, on the contrary, respiration is imperfect, as in asthma, the temperature of the body is lower than natural. Animals which possess a highly developed respiratory apparatus, and consume a great deal of oxygen, have a higher temperature than those which are less favourably endowed in this respect. Thus birds, which consume much oxygen, have a blood warmer, by several degrees, than the human species. In cold-blooded animals, on the contrary, which use but little oxygen, and are able to live a long time without breathing, and in the reptiles, in which respiration is very imperfect, and only a part of the blood is transmitted through the lungs, the temperature is very low. So, animals in a torpid state, in which respiration is suspended, are quite cold. In general, the activity of respiration is a pretty good criterion of the energy of calorification. According to Magendie, it seems to be demonstrated, that respiration produces four-fifths of the heat in herbivorous animals; and three-fourths in carnivorous; and about the same proportion in birds. The developement of heat by respiration, Magendie supposes to be owing to the formation of carbonic acid, whether this takes place in the lungs themselves, by the union of the oxygen of the air, and the carbon of the blood, or, in the course of the circulation, or, even in the parenchyma of the organs. The temperature of arterial blood is higher than that of venous. Holland remarks, that it has been proved, by direct experiment, that the blood acquires at least one degree of heat in passing through the lungs; and as it is computed, that the whole mass of the blood passes through the lungs twenty times an hour, it follows, that the system receives, from respiration, twenty degrees of heat in an hour, or two hundred and forty degrees every twelve hours. Holland considers the lungs as the only source of animal heat; and Magendie as the principal one.

The influence of the nervous system on calorification, is also evinced by many facts and experiments. Brodie's experiments have already been noticed. Great lesions of the nervous system are found to diminish the production of animal heat. Chaussat divided the brain, anterior to the pons Varolii, leaving of course the par vagum uninjured. The circulation was not affected by the experiment, and Chaussat observed that arterial blood circulated in the arteries. Yet in twelve hours the temperature sunk from one hundred and four degrees to seventy-six degrees, Fahrenheit, when the animal died. Heat appeared to be no longer evolved from the moment of the section of the brain. So, when the brain was paralysed by a violent concussion, or a strong infusion of opium was injected into the jugular vein, and respiration was maintained artificially, the result was the same. The par vagum was divided in a dog, and artificial respiration was practised; but the heat began to fall, and death at length took place. The blood was arterialized, and the animal died, not of asphyxia, but of cold. In another experiment, the spinal marrow was divided below the occiput, and respiration kept up by inflating the lungs; but the heat fell, and in ten hours the animal died from cold. The division of the spinal cord lower down, was followed by the same result. In these experiments, however, it is probable that the reduction of the temperature was owing, in part, to the introduction of cold air into the lungs. Concussions of the brain are followed by great coldness of the body. Morbid affections of the nervous system, also, frequently occasion a sensation of cold, and an actual reduction of the animal heat. The temperature of a paralysed limb is generally less than that of a sound one. These facts prove, that the generation of animal heat is, in some measure, influenced by innervation; but whether directly or not, is not apparent. The capillary circulation, and probably all the functions executed by the capillary vessels, are influenced by the nervous system; and if so, it is not improbable that the influence of this system upon calorification is not immediate, but is exerted through its action upon the capillary circulation in the lungs, and the general system. Holland is of opinion, that the nervous system has no influence whatever upon the generation of animal heat, except in diminishing or retarding these chemical changes on which it depends, by destroying the natural proportions of blood submitted to the action of the air.

That calorification is influenced by the state of the circulation, appears from the fact, that a depressed state of this function is attended with a diminished, and an excited, with an increased temperature of the system. In certain malformations of the heart also, as those in which a communication exists between the right and the left cavities, the temperature of the body is below the natural standard.

A phenomenon not easy to be accounted for on any known theory of calorification, is the great developement of organic heat which occurs in febrile and inflammatory diseases. Excessive calorification is a striking characteristic of these maladies; even pulmonary consumption, a disease in which the great focus of animal heat, the lungs, is more or less extensively disorganized, is attended with an increase of the temperature of the body.

Another curious fact is, that in asphyxia and apoplexy, two diseases which assail the calorific power in its very sources, respiration and the nervous system, the heat of the body in some instances continues many hours after death.

From the complex constitution of the blood, as well as its fluidity, we may reasonably suppose that it is capable of a great extent and variety of molecular changes, many of which might be productive of an evolution of heat. It is probable that the constitution of this fluid is such, that so long as it retains its vitality, an indefinite developement of caloric may be possible, by means of various processes, either healthy or morbid, in which it undergoes organic decomposition. There is a fund of power collected and stored up in the blood by hematosis, which in health is prudently, not lavishly, expended on the various functions of the system, while it is carefully and regularly replenished from the proper sources, nutrition and respiration, so as to keep unimpaired the sum of its vitality. In febrile diseases the regulating power appears to be suspended. The healthy constitution of the blood, which itself perhaps is one of the principal checks upon a useless waste of power, is, from the defect of nutrition, as well as the influence of the disease itself, no longer maintained. Its tendency is to rapid and accelerated deterioration; and if the velocity of its motion through the vessels be increased, as in febrile diseases, this tendency, while it is kept within the bounds of *vital* decomposition, is within these almost wholly unrestrained. The power which had been gradually accumulated in the blood, by nutrition and respiration, is now lavished with unrestrained prodigality, and of this waste the increased developement of caloric is one of the most striking manifestations. This excessive calorification is then an evidence of diminished and diminishing organic power in the blood, and the degree of heat is a pretty accurate index of the rate at which this diminution is taking place. The phenomenon may be compared to convulsions arising from debility, or to the preternatural muscular strength occasionally witnessed in the delirium of typhus fever. A remark of Lenhossek, appears to correspond with these views; "Aucto destructionis processu, quo oxygenii vim prostrata vitalitas limitare non ampliùs potest, ut in typho putrido, et partium gangræna est, liber corporis calor nimiùm intenditur."

It seems probable, then, that the vital decomposition of the blood, is the source of the developement of organic heat, as hematosis is of its formation. Hence, all the functions in which an expenditure of the principles of the blood takes place, are accompanied by an evolution of heat, and the heat developed will be greater in proportion to the rapidity with which these functions are performed. When the circulation is accelerated, the decomposition of the blood is more rapid, and more heat is extricated in a given time. If the motion of the blood is hurried by exercise, much of the disengaged heat is carried off by cutaneous and perhaps pulmonary exhalation, and hence there is less elevation of temperature than would correspond with the degree of velocity of the circulation. In fever this is not the case; but on the contrary, the cutaneous exhalation is suppressed or much diminished, and the heat evolved is consequently retained, and accumulates.

In inflammation, the decomposition of the blood is more rapid, because there is a very active, though perverted process of nutrition going forward in the inflamed part, as appears from the morbid products of inflammation, viz. albuminous effusion, exudation of fibrin, false membranes, pus, granulations, &c., and also from the altered condition of the blood itself. The burning pain in a part on the eve of gangrene, or affected with malignant anthrax, or erysipelas, tends to strengthen this view. The blood in these affections is rapidly undergoing the greatest change of which it is capable within the limits of vitality, which it has now almost reached. As it approaches this barrier, which separates it from the domain of physical nature, its last vital energies are powerfully exerted, and the sudden change at the moment of its transition from life to death, is accompanied with the rapid and final extrication of the last remains of its organic heat.

The heat which in certain cases remains several hours after death from asphyxia and apoplexy, is undoubtedly a biochemical phenomenon. It is probably connected with a residual capillary circulation; for we find that some other results of capillary action are not very unfrequently exhibited after death. Thus a profuse sweating has been known to continue for several hours after dissolution. But why the phenonenon should occur most frequently after death from the two diseases above mentioned, although plausible conjectures might perhaps be offered, it is as well to confess that we are wholly ignorant.

CHAPTER XXI.

FUNCTIONS OF RELATION.

The third class of functions embraces those of relation, or the physiological actions by means of which animated beings, and particularly man, are enabled to maintain a communication with the external world. It includes, 1. Those functions by which we receive impressions from external objects, or from the play of our own organs, which, in relation to the sentient principle, may be considered as external. 2. Those by which we variously combine, decompose, and recombine, the sensations resulting from these impressions by an intellectual elaboration, and derive from them the materials or occasions of many internal perceptions, judgments, feelings, and volitions, which, however, cannot be analyzed into them. 3. Those by which we give expression to our feelings, judgments, and volitions, by certain sensible signs, which are produced by the action of certain organs endued with the power of voluntary contraction, and by which we, in our turn, react upon the external world. The first order of these functions embraces those of *sensation;* the second those of *perception,* of the *intellect,* and of the *moral sense;* the third, those of *voluntary action.*

Sensation.

By sensation is meant those physiological actions, by which man and other animals receive and become conscious of various impressions made upon them by external objects, or by the actions of their own organs; or it may be defined more generally to be a perception of the changes produced in the nervous system by external impressions. In its nature it is essentially subjective, for the mind is conscious only of its condition or affections.

The faculty of sensation pervades all parts of the organization which are supplied with nerves, but is variously modified by the texture of the parts, and the quantity of nervous matter which they severally receive, yet every where possesses a certain common character.

At the surface of the body this common power of sensation is modified with reference to certain orders of impressions which it is destined to receive, viz. those from the external world; and about the head, in the immediate vicinity of the brain, the common centre of perception, it receives four special modifications,

having relation to certain specific qualities of external objects, and residing in curiously organized pieces of animal mechanism.

Sensations are divided into two classes, external and internal. External sensations are those which result from the action of certain causes upon the organs of sense; the internal, those which originate in the system itself. The properties of the external world are the objects of external sensation; the actions of the system itself are those of internal. Yet both of these classes of objects or causes of sensation may be considered as external in relation to the nervous system; for every part of the organization, however minute, may be regarded as an outward object, and the whole organism as a kind of outward world, in relation to the nervous system, and its powers of sensation. The condition of every part of the organization, whether healthy or morbid, must be reported, as it were, to the nervous system, and represented to the powers of sensation; and this collective representation of the condition of every point of the living organization, in the affection of sensation, is termed *cœnæsthesis*, or common sensation, in distinction from the representation to our consciousness of the outer world, by means of the organs of sense.

Internal Sensations.

Internal sensations are exceedingly numerous and diversified, but generally obscure and indefinable; though under some circumstances extremely acute and powerful. In a state of perfect health, when the play of every function is easy and unobstructed, and no physical desire is ungratified, the blended mass of internal sensation, arising from every part of the organization, and converging to the common centre of perception, produces an indistinct but agreeable feeling of physical well-being, in which it is not easy to distinguish any single ingredient.

But when the healthy and regular exercise of any function is impeded, either from disease or any other cause, or when any periodical or other want of the system is developed, new sensations are excited in the affected organs, which *stand out* from the general mass of internal sensation. In the first case, viz. that of obstructed function from disease or other causes, these sensations are uncongenial to the mind, or in common language, painful; in the last, i. e. the developement of physical wants, these feelings take the name of desires, and if moderate in degree, are of a pleasurable kind, and instinctively suggest the proper means for their own gratification. If these means are applied, the gratification of these desires is productive of the greatest physical enjoyment of which we are capable. If they are withheld, the feeling of the want becomes more and more urgent, and in the

end uncontrollable and intensely painful. We have then three classes of organic or internal sensation.

1. Consisting of the healthy feelings springing up from every part of the system, while in the easy and natural exercise of its functions, all blended together in a common mass of sensation.

2. Those arising from organs which, from disease or other causes are rendered incapable of performing their proper functions in a natural and regular manner. This class embraces every variety of painful sensation, especially those which are produced by disease.

3. Those which spring from the physical wants developed in the system, either periodically from the laws of the organization, and subservient to its preservation or welfare, or from accidental causes. When not exceeding a certain limit, these feelings are agreeable; beyond it, they change their character, and become more or less painful, and in the end, if they remain ungratified, are in some instances productive of terrible suffering.

4. A fourth class of internal sensations are those which accompany the gratification of the third, and which may be either moderately or exquisitely pleasurable. Hunger, thirst, the desire of sleep, the sexual instinct, and the appetite for muscular motion, belong to the third class. Artificial wants or appetites, as the desire for spirituous drinks, for opium, or tobacco, fall under the same title. The feelings severally accompanying the gratification of these wants, whether natural or artificial, constitute the fourth class.

External Sensations.

The external sensations are the commencement of the functions of relation. They apprise us of the nature and qualities of the external objects with which we are surrounded, and are necessarily in constant intercourse; enable us to observe and distinguish them, and to seek such as may be useful, and to avoid those which are hurtful to us. The second, or the internal sensations, apprise us of the wants of the condition of our own systems.

External sensation is of two kinds, viz. general and special. General or *tactile,* gives us a knowledge of the common qualities of natural objects, as form, dimensions, consistency, weight, &c.; the special inform us of certain other qualities of a more specific and peculiar character, as their colour, taste, smell, &c.

The organs of sensation consist of the common integument of the body, viz. the skin, or of certain pieces of structure curiously organized, and designed to collect and to modify the impressions received from external objects; and of expansions of nervous matter, disposed in such a manner as to receive these

modified impressions. These organs are situated at some part of the periphery of the body, and have a direct communication with the brain or spinal cord, by means of nerves.

It is a curious fact that the powers of sensation, motion, and consciousness may be entirely abolished by a disease affecting a small portion of the brain, and yet the patient live a considerable time cut off from the external world, and even from all consciousness of existence. Serres relates a curious case of this kind, in which there was a complete annihilation of sensation, and of the power of motion. The subject was a female, and the first appearance of the disease was an unsteady gait like that of a person intoxicated. The power of motion and sensibility were gradually impaired, and at length by degrees wholly destroyed. She was insensible to external irritation, her vision was entirely lost, and her taste, hearing, and smell, were totally abolished. In short, the animal functions, or those of external life, were absolutely annihilated for one month before her death. This extinction of the functions of relation, was discovered to be owing to a schirrous disorganization of the pons Varolii, and the place of insertion of the trigeminal nerves. The same writer describes another case which presented the same phenomena, in which the inferior part of the pons Varolii was in a state of ramollescence.

A condition somewhat similar, exists in apoplexy; but in this disease the isolation of external and vegetative life is by no means so complete, for respiration is deeply affected, and hence life is brought to a speedy close.

CHAPTER XXII.

SENSE OF TOUCH.

This sense differs from all the others in the circumstance that it has no peculiar or specific excitant, and that its exercise is not confined to any particular organ, though it belongs in a special manner to the hand, and especially the tips of the fingers, and that it does not require any peculiar or specific sensibility, but only the common powers of sensation, which are diffused over the whole surface of the body. We acquire ideas of most of the physical properties of bodies by means of this sense; as their form, dimensions, weight, temperature, smoothness, roughness, degrees of consistence, distance, motions, &c.

The skin, the structure of which has already been described, is the general organ of touch. The immediate seat of the sense

is the papillæ of the *cutis vera*, or *corium*, which are minute prominent bodies of various forms disposed over the external face of the corium. According to Magendie, they appear to be essentially vascular, and when destroyed are reproduced. They are very sensible; and in them terminate the extremities of all the cutaneous nerves.* The epidermis is perforated opposite the summits of these bodies, with minute orifices, from which escape little drops of sweat, when the skin is exposed to an elevated temperature.

The exercise of this sense is favoured by several circumstances, as the thinness and delicacy of the cuticle, warmth, and a free cutaneous transpiration.

The nerves which are subservient to the sense of touch, are the posterior roots of the spinal nerves, the large division of the fifth, the par vagum, and the glosso-pharyngeal.† The spinal nerves are distributed to the body, neck, occiput, and the limbs; the fifth pair to the face, temples, and fauces; the par vagum and the glosso-pharyngeal, to the pharynx and œsophagus. The nerves of touch are provided with ganglions near their origins.

Different parts of the skin are endued with this sense in different degrees. The hands, and particularly the ends of the fingers, enjoy the most delicate sense of touch. In the hands the skin possesses some peculiarities which adapt it more perfectly for this office. The epidermis is thin and delicate; the transpiration copious, and the vascular *papillæ* more numerous than in any other place. The corium receives a very large supply of blood-vessels and nerves. Further, in the palms of the hands, and on each side of the joints of the fingers, the skin is furrowed to facilitate the closing of the hands, and thus enable them to grasp the objects submitted to their examination. The motions of the hands, also, are easy and very various; so that the organ can apply itself to all parts of the bodies it examines, whatever may be the irregularities of their shape. The tips of the fingers, also, are furrowed on their palmar side, by delicate spiral lines; and externally are supported by horny scutiform appendages, the nails; which are found only in man and the quadrumanous mammalia.

Besides the hands and feet, the whole surface of the body possesses the sense of touch; and even the mucous surfaces of the eyes, nose, and fauces, larynx, pharynx, and œsophagus, the rectum, and urinary canal. The voluntary muscles also appear

* Magendie remarks that the corium receives a great number of nerves, particularly in those parts of the membrane which are most concerned in *touch;* but he says that we are wholly ignorant of the manner in which the nerves terminate in the skin, and that all which has been said of the *nervous papillæ* of the skin, is hypothetical.

† Mayo.

to enjoy a peculiar kind of touch, owing as Mayo supposes to the circumstance, that branches of the same sentient nerves which supply the skin, are distributed to the voluntary muscles in conjunction with the nerves subservient to voluntary motion.

Touch is either active or passive. Active touch is exercised chiefly by the hands. In the exercise of this sense, we apply our hands to the object to be examined, either grasping it with them, or passing the palmar sides of the fingers, particularly their tips, successively over its surface. The motion of the hands or fingers is indispensable to the active exercise of this sense. If one hand merely remain in passive motionless contact with the surface of the body, we receive only very obscure and imperfect sensations, similar to those excited by the contact of the substances with any other part of the surface of our bodies. In order to acquire ideas of the form, dimensions, consistency, &c. of objects, it is not enough that they be placed in contact with our hands; we *must apply our hands to them*, and pass our fingers successively over different parts of their surface, and exert an act of attention to the sensations which we receive. During this tactile exploration of bodies, the papillæ of the fingers experience a kind of *erection*, by which their receptivity is increased, or they are rendered more sensible to the impressions made upon them. It is by this active touch that we get our ideas of most of the tactual properties of bodies, as their shape, size, hardness, or softness, smoothness, roughness, &c.

By the passive sense of touch we derive our sensations of the temperature of bodies, and vague and imperfect ones of their other physical qualities. We receive, also, impressions of various kinds from the chemical and mechanical properties of substances, applied to our bodies. Thus, substances which exert a chemical or corrosive action upon the skin, as the caustic alkalies, strong acids, &c. excite peculiar painful sensations, by which the actions of these substances may be distinguished. So the application of pointed or cutting bodies to the skin excites painful sensations of a peculiar kind. We can also feel the *weight* of heavy substances, placed upon any part of our bodies, though we cannot so well *appreciate* it, as by the resistance it opposes to voluntary muscular contraction.

The resistance to our muscular efforts which material bodies present, is supposed by Brown to be the source of our ideas of hardness, and softness, weight, and of some other physical qualities, which we combine into the idea of matter. Brown denies that the idea of resistance and solidity are derived from the sense of touch; he contends that they originate in the sensation of *resisted* muscular contraction. In support of this opinion he says that if a cube of solid matter be pressed against the palm of the hand, it is true that it will excite a certain sensation of

touch, but not that of resistance, (which always implies a muscular effort which is resisted) and consequently not that of hardness, which is made up of resistance. But if we make an effort to react against the pressure, a feeling of resistance or of hardness will be excited, arising from the obstruction to the muscular effort. With this opinion Abercrombie coincides, for he remarks that "there seems ground for believing that it is by resistance to muscular action that we acquire the notion of solidity, and that this could not be acquired by touch alone." This opinion shows in a striking manner, how ingenious minds may be blinded by a favourite hypothesis to the most obvious facts. And it is remarkable that the very example which Brown has alleged in support of the opinion, appears to be conclusive against it. For any one who will try the experiment, will find at once that he obtains a perception of solidity from a hard body merely pressed against his hand, nearly as distinct as when he resists the pressure by contracting his muscles. And the difference, which is not great, is not in kind but only in degree.

Indeed, so far is it from being true that muscular action is necessary to the perception of solidity, that we get the most distinct notion of this property from parts which are wholly destitute of a muscular structure, and indeed of all power of contraction whatever. These parts are the bones. If a hard body impinges against one of these, it matters little whether the person endeavours to resist it or not, for in either case he will obtain a very distinct perception of hardness and solidity, and in the one case nearly as much so as in the other. The difference is owing to the fact that resistance, especially if accompanied with counteracting motion, increases the force of the impulse. Every boy who has had his shins kicked in playing football, or has received a blow on his face or ribs from the clenched fist of an angry playmate, or has felt a stone come into violent collision with his head, has acquired a very adequate idea of hardness and solidity, without the least aid from the action of his own muscles. The teeth and jaws have a very distinct perception of hardness, as every one knows who has ever had a tooth wrenched from his jaws; and as becomes very manifest merely by gently striking the teeth with a hard substance. And it is worthy of remark, that when we bite a hard substance, the resistance is felt, not in the masseter muscles, by whose contraction the teeth are forced against the substance, but in the teeth themselves.

From these facts it appears that we can obtain the perception of hardness and solidity by the sense of touch, without the aid of muscular contraction. But what would be our idea of solidity, obtained by muscular action alone, without the aid of touch? It

is doubtful whether we could acquire any at all. The only sensation we should experience from the action of our muscles upon solid bodies, would be a very obscure and indistinct feeling of impediment to muscular action, which it would be impossible for us to refer to any external cause without the aid of the sense of touch to inform us that an external object was in contact with our organs. For the organ of touch being paralysed or inactive, would become a non-conductor of sensation in both directions; it would form an impassable barrier, insulating our internal sensations, and preventing the possibility of referring the inward feeling of resistance to muscular action to any external cause.

The following pathological fact is worthy of notice in this place. A gentleman was suddenly seized with paralysis in the act of ascending a stair-case, with a box or small trunk in one of his hands. The first notice he had of the attack, was his perceiving that the box which he held by its handle suddenly became very heavy, insomuch that he could with difficulty support it. In a short time he became comatose, but on the application of proper remedies revived, and lived many years afterwards, though in a state of complete hemiplegia. In this case it is worthy of remark that the feeling of weight, which may be considered as resistance under another form, was not in the direct, but the inverse ratio to the force of muscular contraction, whence it appears that the perception of resistance, so far from being measured by the degree of muscular action which is resisted, as we might suppose from Brown's principles, may be stronger in the exact proportion as the latter is diminished.

It is very easy for any one to verify the same fact by a simple experiment. If we raise a moderately heavy weight with the ordinary muscular action exerted for the purpose, and then gradually lessen the force of the muscular effort till we have reduced it to the lowest degree which is sufficient to raise the weight, we shall perceive the body to become gradually heavier, and on reversing the experiment, we shall arrive at exactly the opposite result; *i. e.* by increasing the effort the weight will apparently diminish.

One mode in which muscular action contributes to the distinct perception of solidity or resistance, is by increasing the firmness and hardness of the part against which the solid substance is pressed; as any one may learn by pressing a hard body first against a muscle when relaxed, and afterwards against the same muscle in a state of rigid contraction.

The mucous membranes possess a very delicate sense of touch. This is particularly the case with that which lines the lips, the tongue, the larynx, the nasal passage, the urethra, and the vagina. The conjunctiva of the eye is also endued with great sensibility.

The contact of foreign bodies with any of these surfaces, is always painful at first; but at length it ceases to be so, or becomes indifferent by the power of habit.

No one of the senses is susceptible of greater improvement by exercise than that of touch; a fact which is strikingly illustrated by the exquisite delicacy of this sense which is acquired by the blind.

Most of the organs and soft solids of the body, like the skin, possess the faculty of transmitting impressions to the brain, when they are exposed to the contact of foreign bodies, or to any kind of mechanical violence.

The bones, tendons, cartilages, ligaments, and fasciæ form an exception to this general fact; since, in a healthy state, they are insensible, and may be divided, burned, or lacerated, without giving notice to the mind by any painful sensation.* The ligaments, however, become affected with most acute pain, when subjected to mechanical violence of a certain kind, as that of wrenching. It is a remarkable fact, that several of the nerves are insensible to mechanical irritation. This, according to Magendie, is the fact with the first, second, third, fourth, sixth, the portio mollis of the seventh, and the branches and ganglions of the sympathetic.

CHAPTER XXIII.

VISION.

The apparatus of vision consists of the eyes, and their appendages. The eyes are two movable globes, lodged in deep sockets, in the upper and anterior part of the head, on the right and left of the root of the nose.

They are composed of various parts, which perform different offices in the complex function of vision.

The eye is a dioptric instrument, constructed with admirable skill, and designed to refract the rays of light, which enter the organ from luminous objects, in such a manner as to form images of them at the bottom of the eye. These images are painted bottom upwards, on a nervous membrane, called the

* Magendie.

retina, which is considered as an expansion of the optic nerve, and is the immediate seat of vision.

The globe of the eye has the form of a spheroid, of which the antero-posterior diameter is the greatest, and in the adult is ten or twelve lines in length. It is composed of various coats, or tunics, inclosing humours of exquisite transparency, and of different degrees of density. The tunics of the eye are four in number, and are severally termed, the *sclerotica*, the *cornea*, the *choroides*, and the *retina*. The humours contained in them, and which constitute the principal part of the bulk of the eyeball, are three in number, viz. the *aqueous*, the *crystalline*, and the *vitreous*.

The external coat of the globe of the eye, is the *sclerotica*, which is a strong, fibrous, opaque membrane, evidently designed to protect the internal parts of the eye, and to serve as a place of insertion to the muscles which move the eyeball. As this membrane is opaque, it is of course incapable of transmitting the light to the internal parts of the eye. But, in the centre of its anterior part, it has a circular aperture, like a window, which is filled by a transparent lamellated membrane, presenting a convex surface anteriorly. This membrane is called the *cornea*. It is the segment of a smaller sphere than the sclerotica, into which it is inserted, something like a watch crystal, and, of course, projects from it. It is ingeniously termed by Arnott, the *bow-window* of the eye. The cornea is thicker than the sclerotica, and is formed of six distinct laminæ, easily separated from one another, and the internals of which contain a limpid fluid. This fluid transudes after death, leaving the cornea opaque and tarnished, and evidently flattened. No nerves, nor blood-vessels, can be discovered in the cornea.

Next to the sclerotica, and lining its internal surface, to which it is connected by vessels, nerves, and a cellular tissue, is the *choroid*, or vascular coat of the eye. This extends posteriorly, as far as the opening through which the optic nerve enters the eye, and forward to the ciliary circle. Its inner surface is contiguous to the retina, without however adhering to this membrane. The choroid coat seems to be almost wholly composed of a multitude of arteries and veins, connected together by a very delicate cellular tissue. It is covered on both surfaces by a kind of black varnish, called the *pigmentum nigrum*, secreted from its vessels, the use of which is supposed to be, to absorb the superabundant rays of light, and thus to temper its intensity. Some anatomists have considered the choroides as a prolongation of the *pia mater*, which forms the neurilema of the optic nerve.

Anteriorly, the choroides is bounded by a ring, or belt, of cellular or nervous matter, of a pulpy consistence, called the *ciliary*

circle, or *zone*. This gives origin to a great number of loose folds, radiating round the crystalline lens, called the *ciliary processes*. The number of these processes varies from sixty to eighty.

Next to the choroid coat, and expanded over its inner surface, is a soft, pulpy, transparent membrane, termed the *retina*, on which are distributed the fibrillæ of the optic nerve. It has generally been considered as an expansion of this nerve, but, perhaps, erroneously. The retina is the most interior of the tunics of the eyeball, and immediately embraces the vitreous humour. It is the most important part of the eye, being the immediate seat of vision.

In the anterior part of the globe of the eye, behind the transparent cornea, and conspicuously visible through it, is a circular membrane, placed perpendicularly, and perforated with a round opening, called the pupil of the eye. The circular curtain itself is the *iris*. Its anterior surface is differently coloured in different individuals; its posterior, like the choroid coat, is covered with a black varnish. The size of the pupil is determined by the motions of the iris.

The humours of the eye, whose office it is to refract the rays of light, are three, viz. the *aqueous*, the *crystalline*, and the *vitreous*. The vitreous, so called from its resemblance to melted glass, fills the posterior part of the globe of the eye, and constitutes by far the largest portion of the eyeball. This humour is dispersed through innumerable cells, formed by a membrane of exquisite delicacy and transparency, and has the appearance of a tremulous jelly. Its refractive power is 1.3394, being somewhat greater than that of the aqueous humour, but much inferior to that of the crystalline lens. It occupies three-fourths of the cavity of the eyeball, is of a spherical figure, with a depression in front, in which is lodged the crystalline lens. This is a small lenticular body, of the most perfect transparency, and convex on both surfaces. Its posterior convexity is greater than its anterior; i. e. it is the segment of a smaller sphere. The crystalline lens is much more dense than the vitreous humour, and is the most important of the refracting powers of the eye. It is composed of concentric laminæ, of which the central ones are more compact and solid than the exterior or cortical layers, and form a kind of solid nucleus on which the former are superimposed. The refractive power of the lens varies in different parts of its substance, being greatest in its central, and least in its cortical portion.

Refractive power of the outer coat, ...	1.3767
Of the middle coat, ...	1.3786
Of the central part, ...	1.3990
Of the whole crystalline, ...	1.3839

The crystalline lens contains a large proportion of albumen, in consequence of which it loses its transparency by the action of a certain degree of heat, as that of boiling water, by acids and alcohol. A similar change sometimes takes place spontaneously, and constitutes the disease termed *cataract.*

The crystalline lens is invested by a membrane called the *capsule* of the crystalline. Between this membrane and the lens, a small quantity of transparent fluid is found, which is called the *liquor of Morgagni,* and which immediately escapes when the capsule is opened. The capsule is covered anteriorly by a lamina of the hyaloid membrane of the vitreous humour. For, near the circumference of the lens, this membrane separates into two laminæ, one of which passes before the lens, as just described; the other behind it, lining the cavity in the vitreous humour which receives the lens. By this separation of the laminæ of this membrane, a small triangular canal is formed, at the circumference of the crystalline lens, called the *canal of Petit.*

The remaining, and anterior part of the eyeball is occupied by a limpid fluid, called the *aqueous humour;* which fills the space between the cornea and the crystalline lens. This space is divided by the iris into two unequal parts, called the *anterior* and *posterior chambers* of the eye, which communicate freely with each other by means of the pupil. Both surfaces of the iris are of course bathed by the aqueous humour. The quantity of this humour amounts to five or six grains. Its refractive power is estimated at 1.3366, that of water being 1.3358. It is secreted by a very delicate membrane, which lines the parietes of the anterior chamber of the eye, and is readily renewed if any cause occasions its evacuation from the eye. This membrane is perforated by the pupil of the eye; but, in the fœtal state, until about the seventh month, it forms a serous sac, without opening, extending over the pupil, so as to isolate the two chambers from each other. The temporary part, which closes the pupil, is called the pupillary membrane. It is usually ruptured, and disappears about the seventh month of gestation, and sometimes earlier. Its persistence, after birth, is said to be one cause of blindness. The aqueous humour consists of water, holding in solution a minute quantity of saline and animal matter. In jaundice it sometimes becomes impregnated with bile, which gives it a yellow tinge.

Muscles of the eye. The eyeball is moved by six muscles, which are attached, posteriorly, to the bottom of the orbit, and, anteriorly, are lost in the sclerotica. Four of these muscles are called *recti,* or straight; and the remaining two, *obliqui,* or oblique muscles. A particular description of their situation and uses belongs to anatomy.

Nerves of the eye. The eye is abundantly supplied with acces-

sory nerves, from different sources, besides receiving the whole of the optic, which is the proper nerve of vision. The optic nerves are of considerable volume in proportion to the size of the eye. They are said to originate from the anterior part of the *tubercula quadrigemina*, and not, as was formerly supposed, from the *optic thalami*. Rudolphi, however, regards this opinion as incorrect; and in confirmation of his own views, he mentions that he had examined the brain of a child, in whom the right eye and its orbit were wanting; while the left was perfectly formed. On dissection, he found the tubercula quadrigemina perfectly alike, on the two sides; while the right thalamus of the optic nerves was abnormal both in size and situation; the left alone presenting the natural characters. From this case, he infers that the optic nerves do not originate from the tubercula quadrigemina, though he does not deny that a connexion may exist between the latter and the origin of these nerves. In their passage to the orbits, the optic nerves approach each other, and unite together at the *sella Turcica*, from which point they again separate and diverge, each passing into the corresponding eye through the *foramen opticum* of the *sphenoid bone*. The nerve does not enter the eye exactly in its axis, but a little nearer the nose. It is invested with a coat, derived from the dura and the pia mater. It has been a subject of much dispute, whether the optic nerves, at their union on the *sella Turcica*, are in the relation of mere juxtaposition, or whether they do not, completely or partially, decussate each other. Various opinions, supported by more or less evidence, have been entertained on this subject. Galen and Vesalius held to the juxtaposition of the optic nerves; the former, from having met with a case of atrophy of the eye, and of the optic nerve, on the same side; the latter, from a remarkable case, in which the two nerves remained separate through their whole course.

Other facts, equally conclusive, favour the opinion of the complete decussation of these two nerves. Thus, Soëmmering found, in seven persons, blind of one eye, that the atrophy of the nerve was on the side *opposite* to that of the affected eye. Richerand and Portal observed blindness of an eye, occasioned by apoplexy, seated in the opposite hemisphere of the brain. Meckel cites cases of complete separation of the optic nerves, through their whole course, from Nicolaus de Janua and Valverde.* A perfect decussation of the optic nerves, without their even adhering together, occurs in fishes with a bony skeleton, with the single exception, according to Rudolphi, of the *gadus morhua*, or cod-fish. Magendie found, that when the optic nerve of one side was divided behind the commissure, the eye of the opposite side,

* Anat. Pathol. vol. iii. p. 399.

was affected with atrophy; and when one eye was destroyed, the nerve of the opposite side behind the commissure withered. Upon destroying the union of the two nerves, by an incision made at their junction, the sight of both eyes was abolished; an effect which appears to establish the complete decussation of these nerves.

Other physiologists contend for the partial decussation of the optic nerves, asserting that only some of the filaments, on the internal side of the two nerves, cross each other; so that each nerve, anterior to the *chiasma,* is formed of filaments derived from the nerve of the opposite side, and partly of those which primitively belonged to it. This opinion was embraced by Wollaston, as affording an explanation of the affection of vision called *hemiopia.*

Berthold cites from Osthoff, the case of a person of forty-eight years of age, affected with hydrocephalus, in which, instead of a chiasma, the two nerves, at the distance of half an inch from each other, were united by a small nerve, passing like a bridge from one to the other.

The case mentioned by Rudolphi appears to disprove the opinion of the complete decussation of the optic nerves; yet he admits that in cases of blindness of one eye, which has continued for a long time, the nerve of the opposite side, behind the chiasma and the corresponding thalamus, becomes smaller or wasted; although the fact that the portion of each optic nerve which is derived from the thalamus of each side, constitutes by far the greater part of it, would lead us, he says, to expect the contrary.

The optic nerve, after piercing the sclerotica and choroid coats, is distributed upon the retina, or, according to some anatomists, is expanded over the choroides in such a manner as to form the interior tunic of the eye.

Besides receiving the optic, the eye is abundantly supplied with nerves from other sources. Thus, the third pair of cerebral nerves is distributed to all the muscles of the eye except the *trochlearis* and *abductor.* The fourth pair is wholly distributed to the superior oblique, or *trochlearis;* and the sixth pair to the abductor. The ophthalmic branch of the fifth pair, also enters the orbit, subdividing into three secondary branches, the *lachrymal,* the *frontal,* and the *nasal,* which are distributed to the eye and the neighbouring parts. The office of these branches of the fifth pair, is supposed to be to bestow common sensibility upon the eye and its appendages. It appears however from Magendie's experiments, that the influence of the fifth pair is necessary to vision. The division of this pair of nerves, within the cranium, was found, not only to destroy the general sensibility of the eye, but almost wholly to abolish vision. It is remarkable, that the nerve of specific sensibility, the optic and its peripheral expansion, the

retina, as well as the motory nerves of the eye, the third, fourth, and sixth pairs, appear to possess no general sensibility. The same is true of those parts of the brain with which the optic nerves are immediately connected, viz. the thalami nervorum opticorum, and the superficial part of the tubercula quadrigemina. Twigs of the facial nerve also anastomose with twigs of the ophthalmic branch of the fifth pair, and are distributed to the orbicularis palpebrarum, corrugator supercilii, and the occipito-frontalis.

The iris receives its nerves from the ciliary, which proceed from the ophthalmic, or lenticular ganglion. This is a small, reddish ganglion, situated on the external side of the optic nerve, imbedded in cellular tissue. It is formed by a twig of the third pair, and the nasal branch of the ophthalmic. The ciliary nerves, varying in number and disposition, proceed from this ganglion, and passing along the optic nerve to the sclerotic coat of the eye, penetrate this tunic, and run between it and the choroid coat to the iris, on which they are distributed.

Blood-vessels of the eye. The eye is supplied with blood by the ophthalmic artery, which is a branch of the internal carotid. It enters the orbit at the foramen opticum, with the optic nerve, invested with a sheath, from the dura mater. In its course, it gives off several branches to different parts of the eye, and its appendages; among which is a small vessel, called the central artery of the retina, which pierces the optic nerve, passing through its centre to the internal surface of the retina, where it divides into a number of minute twigs. One of these penetrates into the vitreous humour, supplies the tunica hyaloidea, and proceeds onward to the capsule of the crystalline lens.

The ciliary arteries are very fine vessels, varying in number, from six to twelve. Some of them derive their origin immediately from the trunk of the ophthalmic artery; and others from some of its branches. Those which originate from the ophthalmic artery itself are the most numerous. They divide into a great number of branches, forming a circle round the optic nerve, pierce the sclerotica near this nerve, and are distributed upon the choroid coat, and the ciliary processes. One or two twigs on each side, pass on between the sclerotica and choroides, to the ciliary zone, which they supply, and afterwards are distributed on the anterior surface of the iris, where they form beautiful circles, by the inosculation of their branches. Those of the ciliary arteries, which arise, not immediately from the trunk of the ophthalmic artery, but from some of its branches, are destined particularly to supply the iris. They also send delicate twigs to the conjunctiva, and the sclerotica, which last membrane they pierce a small distance behind its union with the cornea. These are called the anterior ciliary arteries.

The blood distributed to the eye by the ophthalmic artery and its branches, is returned by the ophthalmic vein, which accompanies the artery in all its ramifications—passes out of the orbit, by the foramen lacerum anterius, and opens into the cavernous sinus.

Besides the essential parts of the eye above described, there are certain appendages to it, called by Haller, *tutamina oculi*, designed to protect the organ from injury, and to preserve it in a proper condition to perform its functions. These are the eyebrows, the eyelids, and the apparatus for secreting the tears.

The eyebrows are two hairy arches, crowning the superior part of the orbit, consisting of cellular tissue, a muscle, termed the *corrugator supercilii*, the common integuments, and short hairs, usually of the same colour with that of the hair of the head, and directed obliquely outwards. The eyebrows give great expression to the countenance, and are also supposed to be useful, in screening the eye from too strong a light. The office of the corrugator supercilii is to knit the eyebrows.

The eyelids are two movable, semi-transparent, crescent-shaped curtains, slightly convex outwardly. The inferior palpebra is composed of the common integuments, which are very thin, of delicate cellular tissue, and of the fibres of the *orbicularis palpebrarum;* the same parts, together with the fibres of the *levator palpebræ superioris;* of an oblong cartilage, called the *tarsus* of the ciliary glands, of eyelashes, and internally, a mucous membrane, called the *conjunctiva*, which is reflected over the ball of the eye. The tarsi are situated at the edge of the eyelids, and serve to give them support, and keep them expanded.

Between the duplicature of the eyelids, lie the ciliary, or meibomian glands, amounting to thirty or forty, in the upper eyelid, and somewhat fewer in the lower. They secrete an unctuous matter which is discharged by the orifices of these glands, at the ciliary margin of the eyelids. These orifices are called the ciliary ducts.

The borders of the eyelids are elegantly fringed with rows of stiff hairs, called the *cilia*, or eyelashes, originating from the integuments, by slender roots. The lachrymal gland is an oval-shaped, glandular body, situated at the upper and exterior part of the orbit, within the external angular process of the frontal bone. Seven or eight excretory ducts lead from this gland, and open on the inner side of the upper eyelid, near the outer angle of the eye. The tears, secreted by the lachrymal gland, pass through these ducts, and are diffused over, and lubricate the eye. Near the inner angle of the eye, on the margin of each eyelid, is a small orifice, called the *punctum lachrymale*. Each of these orifices forms the commencement of a small tube, termed the

lachrymal duct, which passes towards the nose, and opens into the *lachrymal sac*, the commencement of the *nasal* duct, through which the tears are conveyed into the nostrils.

At the inner angle of the eye, between the eyelids, is situated a small conglomerate gland, studded with short hairs. It is a congeries of small mucous follicles, similar in structure to the ciliary glands; and it secretes a thick unctuous fluid, analogous to the secretion of these glands.

The parts of the eye immediately concerned in vision, are the transparent coats and humours, which *refract* the rays of light in such a manner as to form on the retina images of the objects we behold; and the retina and the optic nerve, which, by means of these images, convey the impressions of visible objects to the brain, where they give rise to sensation.

The refracting powers of the eye are the cornea, or the transparent coat, through which we look into the eye, and the three humours, the aqueous, the crystalline lens, and the vitreous.

The mode in which images are formed at the bottom of the eye, on the retina, by the physical action of the transparent parts, will be understood from the laws of optics. Objects are seen by means of the light emitted by, or reflected from them. Light is projected from luminous bodies in right-lined, diverging rays. From every point a cone of these rays is emitted, the apex of which touches the luminous point, and the base of which rests on the body which receives the light. Every body, therefore, in the neighbourhood of a luminous object, will receive cones of rays from every point of the latter, on the side directed to the former. If the receiving body be smaller than the luminous one, it is evident that the cones of light projected from the extreme parts of the latter, must converge together upon the former. So that a compound cone or pyramid of light will extend between the luminous and the receiving body, made up of the cones of rays projected from every point of the former, whose bases meet and are mingled together on the receiving object. This pyramid of light will be truncated, and the direction of it will be the reverse of that of the cones of which it is composed. For its obtuse apex will touch the body which receives the light, being composed of portions of the bases of the primitive cones; while its base, formed of the innumerable summits of these cones, will rest on the luminous body. In this manner all luminous objects seen by the eye, project cones of light upon it from every visible point of their surfaces, and of these cones collectively are composed pyramids of rays, of which the eye is the apex, and the luminous objects the bases.

It has already been observed, that the eye is a dioptric instrument, the use of which is to refract the rays of light which enter it, in such a manner as to form images of visible objects at the

bottom of the eye on the retina. It is here necessary to advert to some other physical laws of light. When light is emitted by one luminous body, and falls upon another, it undergoes various modifications according to circumstances. 1. It may pass through the body on which it falls, either preserving or *changing* its primitive direction, as the case may be, and frequently undergoing decomposition; in this case, the medium through which the light thus passes, is said to be diaphanous, or transparent, and the science which teaches the laws of its transmission is called *dioptrics*. 2. Or, none of it may enter the body on which it falls, but the whole of it may be *reflected* from the surface of the latter; in which case the receiving body is white, and is said to be opaque, and the branch of optics which teaches the laws of the *reflection of light*, is called *catoptrics*. 3. Or, the light may be wholly *absorbed* by the body on which it falls; which, in that case, is *black* and *opaque*. 4. Or, in fine, the light in falling on the object may be decomposed, some of its constituent or colorific rays being absorbed by the body and combining with it; while the rest are reflected from its surface, and give the body its colour. Several of these modifications the rays of light which fall upon the eye are made to undergo. Some of them which fall upon the transparent cornea pass into the eye and traverse the humours, which are exquisitely transparent; some pursuing their original direction, others being more or less *deflected*, or bent out of it. Most of those which fall upon the white of the eye are reflected back. Of those which enter the eye, a part fall upon the coloured ring called the iris, where they are decomposed, part of their constituent rays being absorbed, and the others reflected back from the iris, and giving this delicate membrane its expressive colours. Those rays which pass through the pupil are lost in the depths of the eye, where they are employed in tracing images of objects on the retina, and superfluous ones are absorbed by the black varnish of the choroid coat and the uvea. It is only those rays however, which traverse the humours of the eye, and at last fall upon the retina, which are subservient to vision. Most of these rays in their passage through the eye undergo various modifications, which are essential to the functions of this sense; and an explanation of these is necessary to an understanding of the physical part of vision. When a ray of light is emitted by a luminous body, it undergoes no change in its primitive direction, so long as it continues to move in the same transparent medium, whether air or water, or glass, &c. So, if we suppose several different media forming parallel strata, and a ray of light to fall perpendicularly upon the exterior one, it would traverse all of them without changing its direction. But, if we suppose a ray to pass *obliquely*, out of one medium into another of different density or nature, as out of air into water, or out of glass into air, this ray,

in its transition from one to the other, will experience a sudden change in its direction, and become bent, or *refracted* out of its original course; and the new direction which it will assume, will, according to certain circumstances, be either *towards* or *from*, a line drawn perpendicularly to the surfaces of the two media in contact with each other. In passing obliquely through several parallel strata of different densities, it would change its direction every time that it passed out of one into another, and exactly at the moment of its transition.

It appears, therefore, that for a ray of light to be refracted, it is necessary that it pass out of one medium into another of a different density or constitution; that its direction be oblique to the surface of the latter, and that this be transparent, so as to give passage to the ray through its substance.

The circumstances which regulate the direction in which the ray is refracted, in relation to the perpendicular, are the curvature or sphericity of the surface on which the incident ray falls; the density of the medium which it enters and traverses; and the degree of combustibility of this medium. So, whenever a ray of light passes through a series of transparent bodies, differing from one another in the curvature of their surfaces, their density, and combustibility, it will experience, at every transition, a change more or less considerable in its direction.

When a ray passes obliquely into a different medium, which presents a *convex* surface, or has a *greater density*, or is more *combustible* than that out of which it passes, its new direction will be *nearer* to the perpendicular of the surface of the medium. If it passes obliquely into a medium which presents a *concave* surface, or is *less dense*, or *less combustible*, it will assume, after its refraction, a direction *further* from the perpendicular.

The cause of the refraction of light is supposed to be an attraction exerted by the refracting medium upon the luminous rays. When these fall perpendicularly upon the surface of the former, the attraction is equal on the two sides, and no deviation takes place; but if the line of incidence be oblique to the surface of the medium, the attraction will be unequal on the two sides, and will preponderate on the side towards the perpendicular, so that the rays will be attracted in this direction. A convex surface is favourable to refraction, by increasing the obliquity of the incident rays. Superior density operates in producing refraction, by exerting a superior affinity for the luminous rays. The presence of an inflammable principle in the refracting medium, appears also to increase the affinity of the latter for the rays of light. This curious physical relation led Newton to the most remarkable and fortunate conjecture that both water and the diamond, which possesses great refractive powers, contain inflammable ingredients. The diamond, which is superior to

almost all other substances in refractive power, is now known to be pure crystallized carbon. Another substance, possessing a very high refractive power, is the *bisulphuret of carbon,* a transparent fluid, composed of two combustible ingredients, sulphur and carbon, and highly inflammable itself.

Now a transparent refracting substance may be made of such a shape as to cause the diverging rays of light, which fall upon and pass through it, from any given point, to converge together so as at length to meet in another point, corresponding with that from which they were emitted; and as the surface of every visible object may be considered as composed of an infinite number of luminous points, the corresponding points or foci, into which the rays proceeding from them are collected by such a refracting substance, will collectively form an exact image of the object. A convex glass lens, for example, will cause the rays of light, which enter it obliquely from any object before it, to converge to a focus; that is, it will bend them out of their original directions towards a line drawn perpendicular to its own surface. For all the perpendiculars to the surface of a convex lens would meet at the centre of the sphere of which that lens is a segment. Hence the rays of light which enter the lens from any point in an object before it, in being refracted towards a perpendicular, would be made to converge towards one another, and if prolonged sufficiently, would at length meet at a point or focus more or less distant from the centre of convexity of the lens. And all the points or foci thus formed by cones of rays proceeding from all the points of the luminous object, would together form a perfect image of the object; each luminous point in the object being represented by a corresponding point or focus in the image. The greater the convexity, and the greater the density of the lens, the more will the light be refracted or bent out of its original direction, and the nearer will the focus or image be brought to the centre of convexity of the lens. From these principles, it will appear that the rays of light which enter the eye from visible objects, and pass through the pupil, will undergo successive refractions, until at last the rays proceeding from any given point of the object we are looking at, will, after their entrance into the eye, be made to converge so as at length to be brought to a focus in the bottom of the eye; and in this manner a perfect image of the object will be formed in the eye. All the humours of the eye have a much greater density than the atmosphere; and the eye, when light passes into it, presents on its anterior part the form of a convex lens. Of course, when a beam of light strikes on the cornea, the rays which fall perpendicularly upon it will enter the eye and pass on without changing their direction; but those which strike it obliquely, will, after entering the eye, be refracted towards the axis of the organ, in consequence

of the convexity of the cornea, and the density of the aqueous humour. After taking their new direction towards the axis, or centre of the eye, some of the rays will fall upon the iris, part of them be absorbed by this opaque body, and part be reflected back from it out of the eye, and enable us to see the colour of this delicate membrane. But the rays which pass through the pupil will almost immediately fall upon the crystalline lens, a body which has a much greater density than the aqueous humour, and is convex on both surfaces; and consequently, the rays of light, in passing into it from the aqueous humour, will suffer a greater degree of refraction, and be made still more to converge towards the axis of the eye, and towards each other. The crystalline lens is the principal refracting power of the eye. When it is moved from the eye, or from the axis of vision, in operations upon the organ, it becomes necessary to supply its place by the use of convex glasses. By the convergency which the rays of light experience in passing through the crystalline lens, the intensity of light which falls upon the retina must be increased, because, by means of this convergency, the rays will be collected into a narrower field. Not all the rays, however, which fall upon the crystalline lens, are transmitted through it; part of them are reflected back through the aqueous humour out of the eye again, and contribute to give the organ its brilliancy and sparkling appearance. Those rays which traverse the lens are received by the vitreous humour, and conveyed to the retina, where they unite, in points corresponding with those from which they were radiated in the luminous body, and forming an image which is an exact though inverted representation of the object. This image is inverted, because the rays of light cross each other in passing through the crystalline lens; those rays which proceed from the upper part of the object, uniting to form the lower part of the image, and *vice versâ;* so that the image will represent the object reversed, or upside down.

That this is actually the fact, is demonstrated by experiment. If the eye of an animal, after removing the posterior part of the sclerotica, be placed in an aperture, in the window-shutter of a darkened room, there will be distinctly seen, painted on the retina, the images of such objects as transmit rays of light through the pupil of the eye.

The vitreous humour, which receives the rays from the crystalline lens, has a less degree of density than the latter; and, according to the principles before mentioned, which regulate the refraction of light, the rays, in passing out of the crystalline into the vitreous humour, will be refracted *from*, instead of *towards* a perpendicular to the surface; and it will appear, from considering the direction of this perpendicular, that the rays, in being refracted *from* it, will be made to approach *nearer* to the

axis of the eye, and will, consequently, be rendered still more convergent; so that the vitreous humour, though possessing less refractive power than the lens, yet, by its presenting a *concave*, instead of a *convex* surface, is made to co-operate with the aqueous humour and the crystalline lens, in conveying the rays of light, which pass through the eye, and bringing them to a focus on the retina.

On the whole, the organ of vision consists of a complex apparatus of three refracting powers, by which the rays of light which enter the eye from visible objects, are bent out of their original direction, and made to converge to certain points, or foci, on the retina, corresponding exactly with the points of the objects from which they were radiated, and forming miniature paintings or images of them, on the bottom of the eye. If the rays of light were not thus refracted, but if after entering the eye they continued to pass on, each in its primitive direction, all the rays, proceeding from every point of the visible objects, would be diffused promiscuously, and blended together, over the whole field of vision, so as not to form images on the retina, but only a confused expanse of colour. This may be illustrated in a very simple manner. The rays of light, from the numerous objects without, which enter the window of an apartment, do not form images of these objects on the opposite walls of the apartment, because they are not refracted and collected together into foci, corresponding with the points from which they were emitted, but continue to pass on, each in the direction in which it was projected, after they have entered the room. All the cones of rays, which radiate from every point of the objects visible from the apartment, enter it through the window, and pass on, preserving the same direction, till they strike upon the wall, where they form a mingled mass of light. Now, if the room be darkened, and a small aperture only be left in a shutter, in which is placed a convex lens, the rays of light which enter the room, must first be refracted, in passing through the lens; and they will be made to converge to a focus, at a greater or less distance from the lens, according to its convexity or refractive power, and will arrange themselves in points, corresponding in colour and relative situation, with those of the objects from which they were emitted, so as to form exact, but inverted pictures of them. In a word, the rays of light projected from every point of a visible object which enter the eye, pass through it, fall upon the retina, and form two cones, having a common base. One cone is formed by the rays, as they *diverge* from the luminous point, until they fall upon the cornea, which forms the base of the cone; the second, is formed by the same rays, as they *converge* from this base, in their passage through the eye, until they unite, at a focus, or point on the retina, which constitutes the apex of the cone. As the rays of light, however,

undergo at least three refractions after entering the eye, and change their direction, and become more convergent every time they pass from one humour to another, it is evident that the second, or ocular cone, is a figure composed of parts or *frustra* of three cones, differing from each other in their acuteness, or the inclination of their sides to their bases. The whole body of rays, which enter the eye from the object, made up of the primitive cones, form two pyramids of light, joined together by their summits. The base of the objective pyramid rests on the object which projects the light, and its apex is at the centre of the crystalline lens, where the rays from the object decussate; the apex of the ocular pyramid is also in the centre of the lens, and its base rests upon the retina. On the whole, the mechanism of vision seems to be subservient to the purpose of forming images of visible objects, at the bottom of the eye; and these images, in some way or other, we know not how, or why, are necessary to vision. The eye, in fact, is a true *camera obscura.* The images, formed on the retina, are extremely minute; a fact which depends on a well-known optical principle, viz. that "the size of an image, formed behind a lens, is always proportioned to its distance from the lens, and the image is as much larger or smaller than the object, as it is farther from or nearer to the lens than the object." The little luminous circle, which the focus of a burning-glass presents, is, properly speaking, an image of the sun; and this image is as much smaller than this vast luminary himself, as it is nearer to the lens by which it is formed. On the same principle, not only the vastest object in nature may be painted on a minute spot in the retina of the eye, but a boundless extent of ocean, earth, and sky, with innumerable objects of every variety of shape, colour, and dimension, may be crowded together, yet without the least confusion, and every object preserving its exact proportions, its colour, shape, and relative size, &c. on a little concave, not larger than the cup of an acorn.

In order to be visible, an object must subtend an angle of more than thirty-four seconds.

The offices of the different parts of the eye may be determined in many instances, not only from their structure and situation, but by removing them separately from the eye of an animal, and then observing how the images on the retina are affected by their absence. Thus it is found, that if the aqueous humour be evacuated through a small opening in the cornea, the images formed on the retina appear much larger, and less distinct, and less luminous, than before the removal of the humour; all of which circumstances prove, that the rays of light emanating from the luminous points in the visible objects, are not, as in perfect vision, sufficiently refracted to be brought to corresponding points, or foci, when they reach the retina; but that the summits

of the ocular cones fall behind, or beyond this membrane. The more, within a certain limit, the rays converge towards each other, the smaller, more distinct, and more luminous, will be the image formed on the retina, and *vice versâ*.

The crystalline lens, it has been remarked, is the greatest refracting power of the eye, as is evident from its superior density, and from the convexity of both its surfaces. Its office, therefore, must be to increase the convergency of the rays of light, after passing through the aqueous humour, and to diminish the size, and to increase the distinctness and brilliancy of the images. Accordingly, we find that when the crystalline lens is removed from the eye, the image of an object formed on the retina, is considerably larger than before, but very indistinct and feebly illuminated. The light is weak, because the same quantity is diffused over a much larger surface. The size of the image is said to be increased fourfold, by the absence of the crystalline lens. When it is removed in the operation for cataract, it becomes necessary to supply its place by very convex glasses. In fishes, the crystalline lens is nearly spherical, the iris lying in contact with the cornea, and of course, leaving no space for the anterior chamber of the eye. This great convexity of the lens in fishes, is necessary to increase the refractive power of the eye under water—because the difference of density between the two media, water and the humours of the eye, is vastly less than that between these humours and the atmosphere; and consequently, the refraction of light will be proportionably less. For the same reason, convex glasses are necessary to enable a man to see well under water.

The evacuation of the vitreous humour from the eye, leads to similar results, proving that this also is one of the refracting powers of the organ. If both the aqueous humour and the lens are removed from the eye, the rays of light which enter it will not be sufficiently refracted to form an image on the retina. Sometimes, the focus of the refracted rays, instead of falling exactly on the retina, either falls short of, or is produced beyond it. The former defect gives rise to *myopia*, or short-sightedness, the latter to *presbyopia* or long-sightedness. *Short-sightedness*, which generally occurs in young persons, is usually ascribed to too great convexity of the crystalline lens, or prominence of the cornea, producing too much refraction of the light; in consequence of which, the rays are brought to a focus before they reach the retina; but it has also been supposed to arise from an increase of density in the central parts of the crystalline lens.

Long-sightedness usually shows itself about the age of forty, and arises from a mechanical change in the state of the crystalline lens, by which its density and refractive powers are altered. The variation of density is said to take place most frequently at

a particular point in the margin of the lens, and to require some time to complete its circle. At its commencement, vision is considerably injured; but when the change has become symmetrical round the margin of the lens, a convex lens enables the eye to see as distinctly as before.

The office of the iris is to regulate the quantity of light admitted into the eye. Whenever the organ is exposed to an intense light, the pupil contracts almost to a point, so as to permit only a very small pencil of the contracted rays to fall upon the retina. In a faint light, on the contrary, the pupil dilates so as to open a free passage for the admission of light.

According to Raspail, the dilatation of the pupil follows the gamut of the colours, i. e., with the same degree of light, the pupil dilates more or less according to the colour the eye is looking at. Pure white light causes the greatest contraction of the pupil. At a gray colour it begins to dilate. Yellow causes a still greater enlargement, then green, then blue, then orange, and lastly deep red, which produces the greatest dilatation of the pupil. It appears, then, that each degree of dilatation corresponds with one of the prismatic colours. Now, according to Raspail, the crystalline lens and vitreous humour compose together a single organ formed of a series of layers, like those of a bulbous root. And it is evident that the number of these layers traversed by the luminous rays admitted into the eye, will depend on the degree of dilatation of the pupil. The base of the luminous cone of rays, which must be limited by the aperture of the iris, will of course comprehend more or fewer of these layers, according as this aperture is greater or less. These considerations have led Raspail to the opinion, that each of these layers is the organ of a particular colour, to the perception of which it is particularly adapted; and that in order that the image of an object should appear of a certain colour, it is necessary that the cone of light proceeding from the object, should pass through the series of layers, corresponding to the colour in question. In support of this opinion he adduces the following experiment. If we look at a white surface illuminated with a strong light, it is necessary in order to get the perception of white colour, that the pupil of the eye be contracted, and the eyelids drawn near together, so that the base of the visual cone shall be as small as possible. For if we look at such a surface with a dilated pupil, we shall perceive instead of a white, a yellow or even red colour.* If we look at a yellow surface, with very contracted pupils, and the eyes partly closed, as we naturally do, when the eye is exposed to a bright

* Brewster, from some of his experiments on the eye, deduced the conclusion that when the retina is dilated, under exposure to light, it becomes absolutely insensible to all luminous impressions.

light, we shall perceive a feeble white or gray colour instead of a yellow. In like manner, in looking at a red colour, with a similar disposition of the eye, we shall perceive an indigo, violet, or blackish colour instead of a red. Hence he infers that colours are perceived by distinct organs, or rather by certain definite portions or concentric parts of the same organ. Supposing then the pupil of the eye, at its greatest degree of dilatation, to be divided into eight concentric zones round the centre or axis of the organ, we shall have the seven organs of the primitive colours, the exterior zone or the eighth producing the perception of red, and the interior those of the remaining colours, in the following order, viz. orange, violet, indigo, blue, green, yellow; and the zone nearest the centre giving the perception of white. From these principles, Raspail accounts for the fact that green is the colour which is least fatiguing to the eye, and white and red those which are most so. For in the perception of white and red, the pupil is at the extremes of contraction and dilatation respectively, both of which states are forced, and of course fatiguing; whereas in the perception of green, the pupil is at the intermediate or ordinary degree of contraction, which requires no effort, and consequently is not fatiguing.

The motions of the iris have been differently accounted for. Some physiologists contend that its structure is muscular, and that it contracts like other muscular parts. According to Mr. Bauer's observations, there are two sets of muscular fibres in the iris, one radiated, the contraction of which enlarges the pupil; the other circular, and forming a constrictor, or sphincter of the pupil. Home, Bell, Berzelius, and Magendie, also maintain this opinion. Other physiologists deny the muscularity of the iris, and contend that it belongs to the erectile tissues, and is formed by an interlacement of the ciliary vessels and nerves, connected by cellular tissue; that it dilates or contracts by admitting a more or less considerable quantity of blood, according to the degree of excitation produced by light; the size of the pupil and the quantity of light admitted through it, being determined by the degree of this dilatation or contraction. A majority of physiologists appear to have adopted the latter opinion. Blumenbach says, that the iris does not contain a vestige of muscular fibre. Rudolphi says that he has never seen any thing that deserved the name of muscular fibres, either in the iris of birds, in which Treviranus asserted their existence, or in that of any other animal.* The motions of the iris are determined, not by the direct

* Rudolphi admits, however, that the iris, though not muscular, contracts like the sphincter muscles, whose exterior and inner parts act like antagonists. When the outer circle of the iris contracts, the pupil dilates; when the inner, the pupil contracts. The larger or outer circle predominates in substance over the inner, and of course, naturally overpowers the latter in the energy of its action. Hence after death, or apoplexy, or paralysis, the pupil is dilated. But, during life and health, the smaller

impression of light upon this membrane itself, but by its action on the retina. In an experiment of Fontana, a small pencil of rays was thrown upon the iris, which excited no motion in the membrane; but when it was afterwards directed upon the retina, the iris immediately contracted. Pelletier mentions a case of cataract in the left eye, in which the opacity of the lens was so perfect, that the eye could perceive no difference between night and day. A transition from the most perfect darkness to the brightest light, occasioned no contraction of the pupil, though the light fell directly upon the iris. But, upon opening and shutting the sound eye alternately, the pupils of both eyes contracted and dilated successively. Another fact, which appears to be inconsistent with the opinion of the muscular nature of the iris is, that it seems to be insensible to irritation applied directly to it. Pricking it with a needle occasions no motion in it; yet the application of galvanism is said to cause it to contract. In some species of birds, its contractions appear to be under the influence of the will. Thus, parrots are said to have a voluntary power of dilating and contracting the pupil in viewing the same object, and with the same light.

The section of the optic nerves and the ablation of the tubercula quadrigemina produce permanent dilatation of the pupils. The section of the fifth pair of nerves also occasions immobility of the iris, with this peculiarity, however, that the pupil is contracted. Mayo, however, denies that dividing the fifth pair has any influence upon the iris. It merely produces insensibility of the eyeball. But he asserts, that the section of the third pair paralyses the iris; and it is worthy of remark, that in the eagle, according to Desmoulins, the iris derives all its nerves from the third pair.

That the division of the third pair, as well as that of the fifth, should occasion immobility of the pupil, will not seem surprising, when we consider that the lenticular ganglion, from which the ciliary nerves proceed, is formed by a twig from each of these nerves.

It is remarkable, that in some cases of *gutta serena*, the pupil contracts and dilates freely. The pupil was found dilated by Tiedemann in a marmot during its torpidity. According to Rudolphi, it is generally in this state after death; though he says he had often found it contracted.

Magendie asserts, that the effort required to see minute objects distinctly, occasions a contraction of the pupil. The same physio-

or inner circle gets the ascendancy, in consequence of irritations internal and external, so that, for example, in looking at a near object, or by a strong light, the smaller circle overcomes the larger, and the pupil contracts. Narcotics, employed either internally or externally, either excite the outer, or paralyse the inner circle, and thus produce dilatation of the pupil.

logist found, that if the pupil was enlarged by cutting out a circular piece of the iris, the image formed on the retina became larger.

One important office of the iris is, to serve like the diaphragm of a telescope to correct the spherical aberration of light. When light is refracted by a lens of uniform density, and of a spherical surface, the exterior rays, or those farthest from the axis of the lens, are too much refracted to meet in a principal focus; but they meet and cross each other at a point nearer to the lens. A lens with a spherical surface, therefore, having the same degree of curvature every where, cannot refract all the rays to the same focus. To effect this purpose, it must be flatter towards the edges, so as to diminish the refraction of the exterior rays, or its figure must be that of an ellipse or hyperbola. The same effect may be obtained, however, by excluding the exterior rays, by means of a diaphragm, the aperture of which will permit only the central rays, or those near the axis of the lens, to fall upon it. The iris placed a little in front of the crystalline lens, performs the functions of a diaphragm, preventing the rays of light from falling upon the exterior parts of the lens, and admitting only those rays, which the lens can bring to a focus. The crystalline lens is supposed to contribute to the correction of the spherical aberration. It is composed of concentric laminæ, gradually increasing in density towards the centre. Of course, the exterior or cortical layers, from their inferior compactness and density, will exert less refractive power, than if the lens were of uniform density throughout, and the rays of light which fall upon the lens furthest from its axis, instead of being refracted to a point between the principal focus and the lens, will be prolonged, till they meet at the former on the retina.

The iris is not indispensable to perfect vision, as appears from several cases of congenital absence of this part of the eye. In one of these, described by Behr, the defect was accompanied with great sensibility to light, and extraordinary mobility of the eyes. The child enjoyed perfect vision; but was apparently easier and more comfortable in the evening twilight; and her sensibility to light was so acute, that she could see in almost total darkness. Bright colours, as red and yellow, were most agreeable to her, a fact which appears to form a curious and striking illustration of Raspail's doctrine, that every colour corresponds with a certain degree of dilatation of the pupil, and that red and orange are the colours which cause the greatest.

The use of the choroid coat, which is covered on both surfaces with a black varnish, is to absorb those rays of light which have passed through the retina; as otherwise some of them would be reflected back through the retina, and produce confusion of the images formed on that membrane. In the albinos, the black

matter is wanting, in consequence of which the eyes are extremely tender and impatient of the light, and in the daytime vision is indistinct, while in the night, or by a feeble light, it is not impaired. Magendie remarks, that in persons affected with a varicose state of the vessels of this membrane, the dilated vessels lose their coating of black matter, and whenever the image of an object falls on that part of the retina which corresponds to these vessels, the object appears to be spotted red, owing to the circumstance that the light which passes through the retina, in vision, is not absorbed by black pigment at these points.

The office of the retina is to receive the impressions of visible objects, and by means of the optic nerves to transmit them to the brain. It possesses a specific sensibility to light, a property which constitutes its peculiar and exclusive function in the animal economy; and so natural to this part is the state of excitation produced by the stimulus of light, that other causes will sometimes produce it, and thus light be generated by the eye itself. Thus, pressure applied to the ball of the eye, near either angle, will excite the perception of a luminous circle on the opposite side. A blow on the eye or on the head sometimes produces the appearance of flashes of light. The use of narcotics, the stimulus of galvanism, and the delirium of fever, may give rise to the same appearances. The approach of amaurosis is sometimes announced by bright sparks or flashes of light before the eyes, and what is very curious, these luminous phenomena frequently accompany the confirmed state of the disease, when all sensibility to external light is utterly abolished.

It appears from experiment that the retina, as well as the optic nerve, possesses but little *general* sensibility. Magendie found that the retina might be irritated, and even torn, by a couching needle, without exciting any appearances of suffering in the animal. The general sensibility of the eye, as before observed, is derived from the fifth pair. It appears from the experiments of Magendie, that the co-operation of the fifth pair, which is the nerve of common sensibility, is necessary to enable the retina to exercise its specific functions of receiving visual impressions. It would appear, indeed, from one extraordinary case, mentioned by this distinguished physiologist, that the function of the optic nerve, under some circumstances, may be assumed by some other, probably the fifth. The case alluded to was that of a man who enjoyed the use of his eyes, though a cyst, situated in the course of the optic nerves, had entirely destroyed these nerves, and separated the part anterior to the decussation from the posterior part.

It appears, however, from a curious case of complete destruction of the whole of the fifth nerve on the left side by a tumour within the skull, that the influence of this nerve is not essential to vision.

In the case referred to, a large carcinomatous tumour was discovered occupying the left cerebral fossa of the sphenoid and temporal bones, completely obliterating the foramen rotundum, the foramen ovale, and the greater part of the foramen lacerum anterius. The effect of this destruction of the fifth nerve was, that the eye and nostril of the same side lost their sense of touch, but retained their specific sensibility as organs of sense, for the faculties of vision and smell remained. The sense of smell on the left side was unimpaired, yet sternutatories or other irritating substances, as snuff and ammonia, produced no impression on the Schneiderian membrane, nor provoked any effort to sneeze. Vision, during the early part of the disease, was wholly unaffected, but in its later stages the eye lost its perception of colours; individuals appearing to the patient, as she said, white, like statues. In the tongue, the senses of touch and taste, on the left side, were both extinguished, though the glosso-pharyngeal nerve was uninjured.

To the due action of the retina, it is necessary that the light which falls upon it should be neither very feeble nor very intense. A very feeble light makes no impression upon this nervous tunic; a very intense one, on the contrary, overpowers its sensibility, and produces the effect called *dazzling*. The sensibility of the membrane appears to be exhausted by the sudden and violent stimulus of a strong light, so that the eye for some moments remains insensible to its presence.

It has been ascertained by experiment that the spot in the retina where the optic nerve enters the eye, is insensible to light. The experiment consists in placing two coloured wafers upon a sheet of white paper, about three inches apart, and looking at the left-hand wafer with the right eye, at the distance of about a foot. When this is done, and the left eye closed, the right-hand wafer will not be visible. The same effect will be produced if we close the right eye, and look with the left at the right-hand wafer; and upon examination, it is found that the spot on which the rays from the *invisible* wafer fall, corresponds with the base of the optic nerve, or the place where this nerve enters the eye. If candles or very luminous bodies are used in this experiment instead of wafers, the object which corresponds with the base of the optic nerve does not entirely disappear, but causes a faint cloudy appearance, though wholly unlike an image of the object. Hence it follows, that this spot in the retina is not absolutely insensible to strong light. It appears also that though the base of the optic nerve is insensible to ordinary light, which falls *directly* upon it, yet it is susceptible of luminous impressions from the parts which surround it, and hence, in the experiment above-mentioned, when the wafer disappears, the spot which it occupied, instead of being black, as it would invariably be if the base

of the optic nerve were wholly insensible to light, is always of the same colour as the ground on which the wafer was placed, whether this be white, black, or red, or of any other colour; a fact which proves that this part of the retina is stimulated by light borrowed from the neighbouring parts.

It is a curious fact that we sometimes see objects which are faintly luminous, as a distant light or a faint star, most distinctly by turning the eye a little from them, and when we look directly at them they immediately disappear. This appears to show that those parts of the retina which do not receive the direct rays of light, receive a compensation for this deficiency in a greater sensibility to light.

It has been generally supposed that the eye possesses the faculty of accommodating its refractive power to the different distances of the objects it beholds. The degree of refraction which the light from a distant object undergoes, in order to form a distinct image on the retina, would not be sufficient to produce the necessary convergency in the rays proceeding from an object nearer the eye. The focal point of these rays would not be on the retina itself, but at a greater or less distance behind it. This is evident, because the rays proceeding from remote objects, as they diverge less, will require a less degree of refraction in order to bring them to a focus, than such as are projected from objects nearer the eye. Hence, it appears that a different refractive power must be exerted by the eye, in forming distinct images of near and distant objects. Admitting the existence of such a power in the eye, it is not easy to determine on what mechanism it depends. By some physiologists it has been referred to a supposed action of the ciliary processes of changing the distance of the crystalline lens from the retina. Others suppose that the action of the recti muscles of the eye, the tendons of which extend over a part of its surface, effect a change in the form of the eyeball, by compressing it in such a manner as to cause a certain degree of protrusion of the cornea, and thus to increase the convexity of this tunic, and the distance between it and the retina.

Dr. Young and some others refer the power of adjustment to a change in the figure of the crystalline lens itself; an opinion founded on the supposed structure of the lens, in which Young conceived that he had detected a fibrous appearance.

The mobility of the pupil is another cause which has been called in to account for this effect. The pupil contracts when we look at objects near the eye, so as to admit those rays only which are near the axis of the eye, and which require less refraction than those which are further from it; and on the other hand, it dilates when we look at remoter objects, so as to admit the exterior rays, which are most distant from the axis, and which require for their convergency a greater degree of refraction. So

that the same power of refraction may be made to serve both for near and for distant objects, merely by excluding in the one case, and admitting in the other, those rays which require the greatest refraction. This contraction of the pupil, when we view objects near the eye, may also produce the effect of bringing forward the crystalline lens; for as the base of the iris is connected with the ciliary processes which suspend the lens, the latter will be brought forward, or removed further from the retina, by the expansion of the iris towards the centre of the pupil.

A cause of the indistinctness of images formed by the rays of light which have been refracted by lenses, results from the different degrees of refrangibility of the elementary rays of white light. The consequence of this difference of refrangibility is, that whenever solar light is refracted, it is decomposed or separated into its constituent rays; for those rays which are most refrangible will necessarily separate from those which are least so; and the refracted beams of light, instead of converging to a precise focus, and forming an exact image of the object, will exhibit an indistinct image, fringed with the colours of the solar spectrum. This effect is termed the *aberration of refrangibility*, or the *chromatic dispersion* of light; and it is obviated in the construction of telescopes, by using compound object-glasses, made of different kinds of glass, and which are termed *achromatic*, i. e. without colour.

Many philosophers are of opinion that the eye is an achromatic instrument, with its different refractive and dispersive powers so adjusted to each other, as to destroy this aberration of refrangibility. Euler was of opinion that the achromatism of the eye was owing to the different refractive powers of its humours. Others have referred it to the structure of the crystalline lens, the layers of which, being of different densities and dispersive powers, might correct each other, like the different pieces of a compound object-glass.

It has been a question, why we do not behold objects in the same position in which their images are formed on the retina. We see objects in their natural positions, while the images of them painted in the eye are inverted. Various explanations of this fact have been proposed, but perhaps none of them is perfectly satisfactory. The fact appears to be, that the mind judges of the position of objects, by the direction in which the light proceeds from them towards the eye. According to Brewster, when a ray of light falls upon any point of the retina, in any direction, however oblique to the surface, the object will be seen in the direction of a line perpendicular to the retina at the point of incidence; and as the retina is a portion of a sphere, all these perpendiculars must pass through one point, which may be called the *centre of visible direction;* because every point of an external

object will be seen in the direction of a line joining that centre and the given point. The line of visible direction is a line drawn from the point at which the ray strikes the retina, through the centre of the crystalline lens. Treviranus accounts for it, by supposing that the filaments from the upper part of the optic nerves are distributed to the lower part of the retina, and those from the left side of the nerve pass over to the right side of this membrane. This decussation he supposes not to take place at the commissure, but at the place where the nerves pierce the choroid coat.

According to Sir C. Bell, we judge of the position of objects by the feelings which accompany the motion of the muscles of the eye. "When an object is seen," he says, "we enjoy two senses; there is an impression upon the retina; but we receive also the idea of position, or relation, which it is not the office of the retina to give. It is by the consciousness of the degree of effort put upon the voluntary muscles, that we know the relative position of an object to ourselves."

According to others, we see every object, even our own bodies, in an inverted position; and hence, their relative position is preserved in vision exactly as if they were viewed erect. The part nearest the earth we always consider as the lower part, and that farthest from it as the upper part of an object. Hence, whatever part of the retina the image of the earth falls upon, that part of the image of the object which lies next to it, will always suggest to us the idea of the *lower* part of the object, and *vice versâ.* If we suppose the position of every object to be reversed, and among them the beholder himself, they would appear erect, exactly as before. This is the case with those who live on part of the earth's surface precisely opposite to ourselves. Here the position of every thing is exactly the reverse of our own, and of the objects which exist on this side of the earth's surface. Yet the inhabitants of the opposite hemisphere do not see the objects around them as they appear to our imaginations, upside down, but as they are in fact, precisely as erect as the objects about us appear to ourselves. Leidenfrost, according to Rudolphi, witnessed a case of congenital blindness, in which the patient, a young man, recovered his sight after an inflammation of the eyes, and saw every object, trees, men, &c. in an inverted position. After a time he learned to judge of their position like other men. This would tend to confirm Buffon's views, that originally we do see objects inverted; but that the error is corrected by the sense of touch. Other cases of blindness from birth, however, in which sight has been restored, have exhibited a different result.

Another question which has been raised is, why we see objects single with two eyes. This is supposed to be owing to a certain correspondence and harmony of action between the centres, and

other points similarly situated, of the two retinæ; so that the two images, formed on corresponding parts of the two retinæ, coalesce into one; and those which are formed on points which do not harmonize in action, suggest two visible appearances, although they proceed from one object only. By voluntarily changing the axis of one of the eyes, so that the images shall not fall upon harmonizing parts of the two retinæ, we can, at any time, produce the phenomena of double vision. Blumenbach ascribes single vision with two eyes to the power of habit. Infants, he remarks, at first see double; and the double vision which sometimes remains after certain diseases of the eyes, is gradually removed by practice and experience.

It sometimes happens that double vision affects one eye only. This may happen from the cornea becoming *facetted,* in consequence of ulceration. Beer, according to Rudolphi, relates that he had seen some examples of the kind, in which the patient, with the affected eye, beheld objects double, triple, or even quadruple. So, a double pupil has been known to cause double vision with one eye; as in a case related by Reghellini,* in which, in a person blind of both eyes, the cataract of one eye was couched, and an artificial pupil was formed at the inner margin of the iris. The person recovered his sight, and the eye operated upon received the rays of light, both by the natural and by the artificial pupil; in consequence of which, he was affected with double vision of that eye. If the natural pupil was covered, the patient saw quite as well with the artificial pupil as he could with the other. "A small object sometimes appears double with one eye, when the crystalline lens has ceased to be homogeneous, from age or disease." In some instances, double vision, with one or both eyes, is the consequence of a morbid condition of some part of the brain, or of functional disorder of the optic nerve itself.

The eyes of many insects are polyhedrous, with numerous facettes. Dr. Hooke computed, in the two eyes of a dragon-fly, fourteen thousand facettes, and Lewenhoeck counted twelve thousand, five hundred and forty-four, in another species of this insect. Puget adapted the eye of a flea in such a manner as to see objects through it by means of a microscope. A soldier viewed through it appeared like an army of pigmies; and the flame of a candle seemed like the illumination of thousands of lamps. In insects, a filament from the optic nerve goes to each facette of the cornea. Undoubtedly vision is single in insects with these very compound eyes.

The eye, like the other organs of animal life, is subject to the law of alternate action and repose. It can continue in action

* Rudolphi.

only a limited time; after which it requires a period of repose, before it can resume the exercise of its functions. This law of animal life, in its application to the eye, gives rise to some curious phenomena. If a small space of the retina be exposed to a strong light for a certain time, its sensibility to the stimulus of light is at length exhausted. If, for example, we look for a few moments at a white spot on a dark ground, the point of the retina on which the rays from the white spot fall, will at length become almost insensible to the presence of light; so that if the eye be afterwards directed to a white surface, it will perceive a dark spot in it. Whereas, the other parts of the retina, which have not been stimulated, will become *more* sensible to the stimulus of light, so that the dark spot will appear to be surrounded by a dazzling light.

But it appears further, if we look steadily for a few minutes at a small circle of *red*, as for example a wafer placed upon a white ground, we shall in a few moments perceive a light *green* border playing round the red circle; and if we then remove the eye from the wafer, to direct it to a white surface, we shall see a circle of a pale *green* colour, exquisitely delicate, of the same size as the wafer. This green is called the *accidental* colour of the red. By similar experiments with other colours, we learn that *red* is the accidental colour of *blue; blue* of *orange*, &c.

It appears from observation, that the accidental colour of any primitive one is that colour which, in the prismatic spectrum, is distant from the primitive half the length of the spectrum. It appears also that a primitive and its accidental colour are complementary of each other; that is, that each of them is what the other wants to make it white light; or, in other words, that the primitive and accidental colour, mixed together, will form white light. Now the production of accidental colours depends partly on the physical constitution of white light, and partly on a physiological law respecting the eye. It has been remarked already that the retina, after being exposed a certain time to the stimulus of a strong light, has its sensibility to light temporarily diminished. And it appears further, that if the eye be exposed for a short time to the rays from a particular colour, its sensibility to that colour is diminished, and it ceases to receive any sensible impression from it. When the eye, therefore, after looking for some time upon a red wafer, is directed to a white surface, as to a sheet of white paper, the part of the retina which had been previously stimulated by the red colour, is no longer excited by the red rays existing in the white light, and consequently will not see a white colour, but instead of it that colour which results from a union of all the colours which enter into the composition of white light, *with the exception of the red.* The white light is decomposed by the physiological action of the retina, and one

of its component parts, viz. the red rays, is left out; and the result is, that colour which is formed by a combination of all the other rays.

When the retina is highly excited by the action of coloured light, the accidental colour will be perceived, though much more faintly, even when the eye is shut. This is owing to the light which is transmitted through the semi-diaphanous eyelids.

Function of Vision.

The immediate object of vision is light and its various modifications and colours; and with the perception of these the peculiar function of this sense terminates. But we should form a most mistaken idea of the true value of the sense of vision, if we were to suppose that it had no higher object than to display before the mind a party-coloured and meaningless expanse of light. By the aid of some of the other senses, especially that of touch, and by the exercise of the intellectual faculties, judgment, abstraction, and association, the sensations of colour become signs of other perceptions essentially different, and indeed bearing not the remotest resemblance to them; and the means of suggesting to the mind a variety of ideas and of knowledge, which lie entirely out of the proper sphere of this sense.

By its association with the perceptions of touch, light or colours become the signs of material objects existing without us. By the sense of touch, or, according to Brown, that of muscular action, we acquire the perception of solidity or resistance, which is the basis of our idea of matter; and the sensations of colour excited by material objects, coalescing with these perceptions, become signs of them, and ever afterwards suggest them to the mind.

The magnitude, distance, form, and motion of objects, are other perceptions, not originally derived from vision, but which at a very early period become intimately associated with certain sensations of colour, and always afterwards are instantly suggested by them.

The perception of magnitude is derived from the sense of touch or muscular feeling, and, as Brown supposes, involves the perception of time as one of its elements. It is generated by the succession or series of feelings which arise while we are exploring by the motions of the hands or arms, bodies within our reach, and it is estimated by the amount of these motions, or of the time employed in executing them. As all magnitude is relative, we very soon form certain arbitrary standards by which we measure other magnitudes. Now the tangible magnitude of objects becomes associated not with their colour merely, for this may vary without affecting their magnitude, but with the *limitation of their*

colour, and thus this visual perception becomes the sign of their actual magnitude. This limitation of colour, however, is not strictly speaking a sensation of vision. It is a perception formed by an act of the understanding exerted upon the sensation. For the sensation itself does not and cannot know that it is itself circumscribed within certain limits, for it knows nothing, it is a mere feeling; and that this feeling is in any respects limited, must be known, if known at all, by a higher power of the mind. We have then three distinct factors of our perception of magnitude. The first is the perception derived from touch or muscular contraction, involving time or succession as one of its elements; the second, the sensation of colour excited by the body the magnitude of which we are estimating; and thirdly, the perception of the limitation of the colour, which is an act of the understanding. Thus this perception, which is formed instantaneously from the sensation of colour, becomes the sign of the real magnitude of the object; and the advantage of this sign is, that it exterminates from the perception the element of time or succession introduced into it by the sense of touch; so that a momentary glance of the eye supersedes the necessity of the tedious process of a gradual exploration by touch.

We judge of the magnitude of distant objects sometimes, by comparing them with others of known magnitude at the same distance, or by comparing their apparent magnitude with their known distance; keeping in mind the principle that these two quantities are in the inverse ratio to each other, or that one increases in the same proportion as the other diminishes.

We judge of the distance of bodies from their apparent magnitude, by reversing the application of the principle just mentioned; from the number and magnitude of the intervening objects; from the effort of the eye to accommodate itself to the distinct vision of the objects; from the brightness or faintness of their colours, and the clearness or indistinctness of their outline; and from the angle of convergency of the two axes of the eyes.

The perception of figure, according to Brown, is formed by a similar process to that by which we obtain our knowledge of magnitude; *i. e.* by a process of tactual and muscular exploration. He does not admit that we obtain from vision any original perception of figure whatever. This opinion, however, is liable to some doubt. The tactual idea of figure is a very imperfect one, and the reason probably is, that it is acquired in a progressive manner. The elements of which it is composed do not co-exist in the mind, but involve time or succession. They are presented to the mind, not at once, but piecemeal as it were; and it is a difficult task to the imagination to combine together numerous sensations, acquired at different times, into one co-existent whole. The advantage which the sense of vision possesses is

that, as in the perception of magnitude, it unites the scattered elements of touch, so as to embrace *one whole side* of the perception in a single glance, and to exterminate from it the idea of time. The truth is, that our idea of figure is a compound one, containing elements derived from both senses, touch and vision; but a fact which seems to prove that the visual ingredient predominates is, that the word figure or shape always suggests the idea of something visible, and never, perhaps, that of something merely tangible. Without the aid of vision the idea of figure would be extremely imperfect. It would be very difficult, *e. g.* without this sense, to combine the various perceptions of touch, excited by a body of very irregular or complicated shape, into one mental conception.

It is also a curious fact, that if a solid substance with which we are unacquainted is placed in our hands without our seeing it, the perceptions of touch which it excites, instantly suggests an idea of its visible figure, though we know nothing of its colour, the peculiar, and, as we are taught, the only object of the sense of vision. The reason of this effort of the mind is, that the aid of vision is indispensable to our getting rid of the idea of time or succession, so as to combine all the different elements of the perception into one, by substituting the relation of co-existence for that of succession.

That it is possible to obtain an original perception of figure from vision, seems probable from the well-known experiment of pressing one corner of the eye with the end of a finger; a luminous figure makes its appearance, which we instantly perceive to be circular, although no tangible object exists by which it was excited. Hence neither touch nor any other sense could have any possible concern with this perception.

We are not to forget, however, that the perception of figure, whether derived from the sense of touch or that of vision, is not a sensation, but an intellectual act. And the only question is, whether the understanding can perform this act on sensations derived from vision alone, so as to acquire the perception of visible figure. Why it cannot is not very apparent.

Visible figure, however, bounds only plane superficies, and is made up of length and breadth, without thickness.

CHAPTER XXIV.

HEARING.

The organ of hearing consists of a very curious and complicated apparatus. It is divided into an external, a middle, and an internal part, besides the auditory nerve, which is the immediate instrument and seat of hearing.

The external ear consists of an irregular, cartilaginous body, to which the term ear is popularly applied, and of a canal which extends from the external ear, inwardly, and is bounded by a tense membrane called the *membrana tympani.*

The external ear, or pavilion, is composed of a number of elastic fibro-cartilages, moved by a set of muscles proper to it, and covered by a fine skin, attached to the lateral part of the head on each side, below the temple, in front of the mastoid apophysis, and behind the cheek. Its external face presents a very irregular surface, varied by several eminences and depressions, which have received separate names.

The canal, which is called the *meatus auditorius*, or the auricular canal, extends from the bottom of the pavilion to the cavity of the tympanum, from which it is separated by the membrane of the same name. Its length is about ten or twelve lines. Its direction is obliquely forwards and inwards, and its course a little curved, so as to present a convexity upwards. The skin which covers it presents a great number of minute orifices, or pores, which are mouths of the excretory canals of the ceruminous glands of the ear, which secrete the yellow bitter matter called the cerumen of the ear.

The middle ear, or cavity of the tympanum, is an irregular, hemispherical cavity, hollowed out in the petrous part of the temporal bone, and separated from the external ear by the membrane of the tympanum. This cavity has six openings, a chain of four small bones, and several muscles and nerves. The cavities are, 1. Outwardly, the internal orifice of the meatus auditorius, closed by the membrane of the tympanum. This is a thin, transparent, fibrous membrane, of an oval shape, and a little larger than the opening it is designed to close; so that it is capable of alternate motions of tension and relaxation. It is generally convex towards the cavity of the tympanum. According to Home, its fibres, in some large animals, as the elephant, are of a muscular nature. 2. A small orifice, the mouth of a short canal, which communicates with numerous cells, in

the mastoid apophysis. 3. Inwardly, and nearly opposite to the membrana tympani, is a third orifice, called the *fenestra ovalis,* forming a communication between the middle and the internal ear. It is closed by a fibrous membrane, to which is attached the base of the stapes, one of the small bones of the ear. 4. A round opening, called the *fenestra rotunda,* by which the middle ear communicates with the external scala of the cochlea, closed, like the former, by a membranous expansion. 5. At the anterior and inferior part, a small orifice, which is the mouth of a tunnel-shaped canal, about two inches in length, which opens in the posterior part of the nasal fossæ behind the velum of the palate. This is called the Eustachian tube. 6. A sixth orifice, is a small fissure, called the glenoidal, through which passes the tendon of the anterior muscle of the malleus, and a nervous filament called the *chorda tympani.* A chain of small bones, four in number, occupy the cavity of the tympanum, extending from the membrane of the tympanum, to that which closes the fenestra ovalis. The name of these bones, beginning with that which is attached to the membrana tympani, are the *malleus,* the *incus,* the *os orbiculare,* and the *stapes.* These ossicles are articulated together in the order above mentioned, and are moved by three small muscles, viz. the anterior and the internal muscles of the malleus, and the muscle of the stapes. By the action of these muscles, the chain of bones, and the membranes to which they are attached, may receive a greater or less degree of tension. A branch of the facial nerve penetrates into the middle ear, and bestows motility upon these muscles. The middle ear also receives filaments from the spheno-palatine ganglion. On the inner side of the membrana tympani, is distributed the chorda tympani, a twig of the facial nerve. The cavity of the tympanum is lined with a mucous membrane, which is prolonged into the Eustachian tube.

The internal ear is composed of several irregular cavities, excavated in the petrous part of the temporal bone. These cavities communicate with one another, and are divided into three parts, viz. the *vestibule,* the *semicircular canals,* and the *cochlea;* and are collectively termed the *labyrinth.*

The vestibule is an irregular cavity, situated on the inside of the tympanum, exterior to the internal auditory canal, in front of the semicircular canals, and behind the cochlea. As its name imports, it serves as a kind of antechamber to the semicircular canals and the cochlea. In the vestibule are found several foramina, viz. the internal orifice of the fenestra ovalis, covered by its proper membrane, and the base of the stapes. On the posterior side, five apertures, by which the three semicircular canals open into the vestibule; on its anterior side, a large aperture, by which the cochlea communicates with the vestibule; at its inner

surface are numerous small holes, which give passage to blood-vessels, and to filaments of the acoustic nerve, and which communicate with the meatus auditorius internus. Besides these, there is a small foramen near the common orifice of the two vertical semicircular canals, which is the mouth of a very narrow duct, which opens about half an inch behind the meatus auditorius internus, into a small cavity, between the dura mater and the bone. This is called the *aqueduct of the vestibule.*

The three semicircular canals are situated posterior to the vestibule, each forming nearly three-fourths of a circle. They are excavated in the petrous part of the temporal bone, and they open by both their extremities into the vestibule, by five orifices. Their direction is different, two of them being vertical, and the third horizontal. Their walls consist of a compact plate of bone, lined with a periosteum, within which is contained a watery fluid, and a delicate pulpy membrane, on which is distributed part of the auditory nerve.

The third part of the internal ear is the cochlea. This is a spiral canal, forming two turns and a half, and having some resemblance to a snail's shell. This canal is hollowed out of the anterior part of the petrous portion of the temporal bone, before and within the vestibule, and is divided into two parts, by a delicate, semi-osseous, spiral partition, which winds round a central conical pillar, termed the *modiolus.* The two canals which are thus formed, are called *the scalæ* of the cochlea. The modiolus itself is hollow. One of the scalæ of the cochlea opens into the cavity of the tympanum, by the fenestra rotunda; the other, into the vestibule. They communicate together at the summit, by a small aperture.

The base of the modiolus is perforated with several minute foramina, through which the filaments of the auditory nerve penetrate into the cochlea.

The auditory nerve, the eighth cerebral nerve, arises from the medulla oblongata, passes obliquely outwards, forwards, and upwards, and enters the meatus auditorius internus, the orifice of which is situated at the posterior surface of the *pars petrosa.* The base of it is cribriform, and corresponds to the base of the cochlea, and the inner surface of the vestibule. Here, the auditory nerve, dividing into minute threads, enters the labyrinth. The anterior fasciculus of these filaments is distributed to the cochlea; the posterior, upon the vestibule and the semicircular canals.

All the cavities of the labyrinth are filled with a watery fluid, termed the *liquor of Cotunnius,* secreted by the membrane which lines them. This fluid is supposed to be necessary to hearing, since deafness sometimes results from the absence of it.

The human ear, it will appear then, consists of a large irre-

gular, cartilaginous substance, commonly called the ear, a blind canal passing from this towards the internal ear, closed by a tense elastic membrane; beyond this membrane, a cavity filled with air, and communicating with the atmosphere by means of a canal which opens into the superior part of the pharynx; a chain of small bones contained in this cavity, and connected by one extremity with the membrane above mentioned, and by the other with the internal ear, the immediate seat of the sense of hearing, which is composed of various cavities and canals, excavated in a part of the temporal bone, lined with a delicate membrane, filled with a limpid fluid, and having distributed over them the minute branches of the auditory nerve.

Reduced to its greatest simplicity, the organ of hearing consists merely of a sac inclosed in a hard cartilaginous or bony case, with nerves distributed over it, and filled with a watery fluid; so that vibrations affecting the hard elastic walls, may be communicated to the contained fluid, and the nerves distributed over the sac. Such is the internal ear in some of the lower orders of animals. As the organ becomes more complicated, we find added to this simple sac some circular canals filled with water, communicating with that of the primitive sac, or the vestibule. Over the membrane lining these canals, nerves derived from the auditory are distributed; and consequently a larger nervous surface is exposed to the vibrations of sound. In reptiles and fishes, there are small sacs in the labyrinth, containing little stones, or chalky bodies, which perhaps are the first rudiments of a cochlea. In birds, the cochlea is more developed, though still imperfect. To these more essential parts are successively added, as the organ is more fully developed, the middle ear, the chain of small bones, the cartilage of the ear, the more perfect developement of the cochlea, &c.

Sound is excited by the vibrations of elastic bodies, which cause corresponding undulations in the air, and are conveyed by it to the organ of hearing. The particles of sounding bodies, when put in motion by percussion, vibrate backwards and forwards through very small spaces, by their elastic force. This is evident in the string of a violin, and in the motion of a bell. When, by any force, an elastic string is bent out of its rectilinear direction, as soon as the force ceases to act, it will return to it again, by its elasticity, and acquire such a velocity as will carry it nearly as great a distance in the opposite direction. Here too, its elasticity sets bounds to its further progress, and brings it back to its former position, and a little beyond in the contrary direction. In this manner it continues to vibrate backwards and forwards, through small and constantly decreasing spaces, until its motion is destroyed by the resistance of the medium in which it vibrates, or by friction. In like

manner, when the circular edge of a bell is struck by a hammer, the part which receives the stroke, is forced forward by it, so that the circular shape of the bell's mouth is changed into an oval. But the elasticity of the metal, will restore to its former position the part of the bell which the percussion had forced out of it, and the velocity acquired by the stroke will carry it some distance in the opposite direction.

It is a curious fact, that the vibrations of sounding bodies begin in certain points, which are quiescent, and are propagated from these points in opposite directions; and that the number and position of these points give rise to the differences of sound. By sprinkling sand upon sounding bodies, the particles of it will arrange themselves in certain figures which will be determined by these vibrations, and thus we may be figuratively said to *see the shape of sound.*

The same stroke which makes a string or bell vibrate, causes it to sound also, and as the vibrations decay, the sound becomes fainter. When the particles of a sonorous body have been put into motion by percussion, they communicate the motion to the elastic bodies which surround them; these act in a similar manner; and, in this way, the vibratory motions may be propagated to a considerable distance. Elastic bodies, and these alone, are in general capable of producing and propagating sound. The ordinary medium of sound is the atmosphere. When there is no air in contact with the vibrating body, no sound will be heard, unless the body be surrounded with some other elastic medium. Hence, in the exhausted receiver of an air-pump, the sound of a small bell becomes very faint, and if the air could be entirely exhausted, would not be heard at all. In rarefied air, sound becomes weaker; in condensed air, louder. In the air of a diving-bell, condensed by the pressure of the water at a great depth below the surface, the voices of those inclosed in it, it is said, seem much louder than in the open air. This is probably owing to the increased elasticity of the air, occasioned by its condensation. It appears from observation, that sound is louder in oxygen gas than in hydrogen or carbonic acid. If a person inhale hydrogen gas, and then speak, his voice will be scarcely audible. Vibrations are readily communicated to the air by a sounding body. The air in immediate contact with the vibratory body, receives a stroke by every vibration, by which it is propelled forward, and by that means condensed. This condensed portion of air, by its elasticity, will expand itself in all directions, so that it will condense the stratum of air, which lies immediately beyond it. This will produce a similar effect, expanding by its elasticity, and condensing the air that lies still further beyond. In this manner, the motion, at first impressed upon the air by the vibrations of the sounding body, will be propagated continually

forwards, by a chain of undulations in the air, until it reaches the ear. These condensations of the air, produced by sounding bodies, are called pulses.

Other media besides air, are capable of carrying sound. It is said, that sound can be heard much further under water, than in the open air. A very low sound is easily communicated through wood. Even stone is said to conduct it better than air. Indeed, solid bodies transmit sound with greater rapidity than the air. Hasenfratz and Biot found, that when the ear was applied to one end of a long wall, and the other end was then struck, two sounds were perceived, one of which first reached the ear applied to the wall, and the other arrived a little later through the air, to the other ear. An iron bar suspended by two strings, the ends of which are applied to the two ears, will, if struck very slightly, produce sounds in the ear which could not have been heard but for this or some other equivalent arrangement. Very slight and distant sounds may often be heard by applying the ear close to the ground. I was informed by a very aged and venerable lady,* now living, that at the time of the battle of Bunker's Hill, the explosions of the cannon were distinctly heard near her house, in Hanover, New Hampshire, at a distance of nearly one hundred miles from the scene of action, by putting the ear to the ground. In water the velocity of sound is about four thousand nine hundred feet, or nearly a mile, in a second, which is more than four times as great as it is in air.

Ice is a better conductor of sound than even water. If a cannon be fired at a distance, on one side of a broad sheet of ice, as a frozen river, a person on the opposite side will hear two distinct reports after every flash, the first of which is conveyed by the ice, the other by the air.

The body itself may be a conductor of sonorous undulations. Thus, when we touch a sounding body with the ends of the fingers, we perceive a sound caused by a propagation of sonorous oscillations, through the body to the ear. This will enable us to explain those cases, in which the external ear, and even the external auditory canal, have been wanting, and yet the sense of hearing has existed in tolerable perfection. A case of this kind is mentioned by Heister, in which the hearing was very acute. Another is mentioned by Wright; and the author has been informed, that there was a man recently living at Windsor, Vermont, who had no external meatus, yet could hear tolerably well. Mojon considers the cranium as a kind of harmonic case or drum to the organs of hearing; an opinion founded on the facts that deaf people can in many cases, distinctly perceive the sounds

* The widow of the late Hon. Jonathan Freeman, formerly member of Congress from New Hampshire.

of a piano or organ by applying one end of an iron rod to the musical instrument, and the other to the forehead; and that they can be made to hear words addressed to them, if the voice be directed by a speaking trumpet to some part of the forehead. Persons hard of hearing, who wear wigs, it is also said, can hear much more distinctly by listening bareheaded. Another curious fact connected with this subject, which was noticed by Perier, is that persons who have been trepanned, are capable of hearing very distinctly sounds directed to the cicatrix, even with both ears carefully plugged up. But the fact which first drew the attention of Mojon to this subject, was that in the post mortem examination of a celebrated musician, the bones of the cranium were found to be much thinner than usual, and in many places even translucent and soldered together at the sutures. In another eminent musician, Mojon subsequently found a similar condition of the bones of the cranium. From these facts he was led to the opinion that the cranial walls are by no means passive in the perception of sounds, but that differences of thickness in the bones of the head, may have considerable influence on the degree of acuteness of the sense of hearing.

A curious fact in relation to sound, is that all kinds of sounds, however varying in intensity and quality, are transmitted with equal rapidity through the air, and without being confounded together. The pulsations of the atmosphere, produced by a variety of sounding bodies, appear never to become blended and confounded together; but each preserves its own individuality, and produces its peculiar impression on the ear.

Sound, like light, is capable of reflection. The pulses of sound, falling upon certain bodies which obstruct their progress, experience a repercussion, which forces them back, and produces a reflected sound or echo.

The vibrations of a sonorous body, in order to produce sound, must succeed each other with a certain degree of rapidity. It has been calculated there must be, at least, as many as thirty-two, and not more than twelve thousand, vibrations in a second, in order to be heard by the human ear; but according to Savart, the limits of audible sounds are much wider. The gravity and acuteness of sounds depend on the rapidity of the oscillations; their loudness or strength, on the extent of the sonorous vibrations. The tone produced by very rapid vibrations, is termed *sharp*, or *acute;* that which is caused by very slow oscillations, is called *grave*. The gravest sound which can be appreciated by the human ear, it is said results from thirty-two vibrations in a second; the acutest, from eight or twelve thousand, comprehending a range of eight octaves. But according to Savart, the gravest sound which the ear can appreciate, is caused by fourteen or sixteen vibrations

per second; and the acutest audible sound results from forty thousand oscillations in the same time.

We are less acquainted with the offices of the different parts of the ear, in the function of hearing, than with those of the various parts of the eye, in that of seeing. Of the uses and modes of action of the internal ear, we are almost wholly ignorant. The offices of the external and middle parts, are more intelligible. The cartilage of the ear seems to be designed to collect together, and condense the sonorous undulations of the air, and to direct them into the external auditory passage. It is asserted by Boerhaave, that the external ear is so formed, that all the vibrations of the air which fall upon it, are eventually reflected into the external meatus. This is undoubtedly erroneous. At the same time, the general office of the external ear probably is, to collect together the sonorous vibrations of the air, and to conduct them into the auditory passage. The pavilion of the ear, however, is not essential to hearing. Many animals, whose hearing is very acute, are destitute of it; and the loss is said to affect the sense but very little.

The rays of sound, as they are figuratively termed, converging into the narrow canal of the external meatus, are conveyed through this passage, and are received by the membrana tympani. This being a tense, dry, and elastic membrane, readily receives the oscillations of the air, and communicates them, both to the chain of small bones, contained in the middle ear, with one extremity of which it is connected, and to the air existing in the same cavity. The chain of bones, which are elastic substances, propagate the vibrations to the *fenestra ovalis*, and the air of the tympanum, to the *fenestra rotunda*. By the *oval fenestra*, which is covered with a membrane to which the base of the stapes is attached, the oscillations are converged to the fluid of the vestibule; and by the *round fenestra* they are transmitted to the water contained in the inferior scala of the cochlea. The water of the vestibule propagates the vibrations to that of the superior scala of the cochlea, and the semicircular canals; whence the oscillations are directly conveyed to the branches of the auditory nerve, distributed upon all these parts.

It is supposed that the membrana tympani is made tense or relaxed by the action of the chain of bones connected with it, which are moved by the small muscles attached to them. This is probably true. But it is still undecided what circumstances give rise to the changes in the degree of tenseness of the membrana tympani. Bichat supposed that they are connected with the strength or intensity of the sound. Hence very loud sounds sometimes occasion a rupture of this membrane; an accident to which artillery men are liable. Willis mentions a lady, who was

unable to hear sounds of ordinary loudness, but who could carry on a conversation in a low voice if a drum were beat in her apartment.

Others suppose that the tension varies with the degree of acuteness or gravity of the sounds. Whatever may be the real mode of its action, the integrity, and even the presence of the membrane of the tympanum, are not essential to hearing. It is sometimes punctured without impairing the sense, and it is said, may even be torn or entirely destroyed, without essentially injuring the hearing. In the elephant, according to Home, the membrana tympani possesses a muscular structure, by which it is capable of contracting, or of becoming relaxed, according to circumstances. The uses of the chorda tympani are not known.

The small bones of the ear, are supposed to convey the vibrations of sound from the membrana tympani to the internal ear, and to stretch or relax the membranes to which their extremities are attached. They are not, however, essential to hearing; for they are sometimes destroyed without deafness being the consequence. It is worthy of remark, that in birds, which enjoy great acuteness of hearing, three of the ossicles of the ear are wanting.

The office of the Eustachian tube is to procure the introduction of air into the cavity of the tympanum; and also to secure an equilibrium between the air contained in the cavity of the tympanum and the external air. A loss of this equilibrium produces unequal pressure on the external and internal surfaces of the membrana tympani, forcing it outward or inward, according as the inward or outward pressure predominates, and materially affecting the delicacy of its vibrations. Tinkling, buzzing, or other anomalous noises in the ears are produced by this condition of the membrane of the tympanum. The loss of equilibrium may be the result of barometrical variations in the atmosphere, which are very great. It is essential to hearing, the closure of it always producing deafness. It is supposed to perform the same office as the hole which is made in the side of a drum, to qualify the instrument to yield a proper sound. It is a mistake to suppose that it conveys the sonorous vibrations to the ear. If a watch be placed in the mouth without touching the teeth, the ticking of it is scarcely perceptible.

The use of the mastoid cells is not known. But they are supposed to perform the same office as the cavity of the tympanum, with which they communicate. In man, in whom this cavity is of considerable dimensions, they are but little developed, forming in fact only a kind of spongy tissue; while in birds, in which this cavity is comparatively small, they are of great extent.

Of the respective functions of the different parts of the labyrinth

we are ignorant. Probably they are all necessary to the sense of hearing. The absence of the liquor of Cotunnius, according to Pinel, is one cause of senile deafness. A regular supply of blood is necessary to hearing as it is to every other function. Mr. Swan mentions the case of a young man, in the last stage of a consumption, and reduced to great weakness, who was deaf in the erect position, but recovered his hearing as soon as he became recumbent; a fact which illustrates the agency of the blood in sensation, which Mr. Swan refers to its distending the vessels, which thus stimulate the nerves. In the case mentioned by Mr. Swan, it was remarkable that the erect position, though it occasioned deafness, did not appear to affect the functions of the brain.

CHAPTER XXV.

SENSE OF SMELL.

By the sense of smell, we perceive the impression of odours upon the internal surface of the nose. Odours, or smells, are excited by extremely minute particles of matter, which escape from all odorous substances, and are diffused through the atmosphere to a greater or less distance from their source, and, being drawn into the nostrils in the act of inspiration, and coming into contact with the lining membrane of the nose, give rise to the sensation of smell. Those substances which have no volatile particles, and which consequently do not suffer any to escape into the atmosphere, are termed *inodorous*. Water, though a fluid, and readily evaporating, is nevertheless destitute of smell.

The organ of smell consists of a cartilaginous prominence, of a somewhat pyramidal shape, situated in the middle of the face; divided internally by an elastic partition into two equal parts; and presenting at its inferior part, two orifices, termed nostrils, which are the anterior openings of two cavities, termed the *nasal fossæ.* Internally it is composed of these fossæ, which commence anteriorly at the nostrils, and terminate posteriorly by two openings in the pharynx. Each of these cavities forms an irregular triangular canal, with its base below. On the inner side, they are bounded by the septum narium, and on the outer by the turbinated bones, which project into the nasal cavities, and increase their surface, and the extent of the sensible part of the organ. By means of these bones, the nasal canals are divided on each side into three passages, by which the air may pass from

the nostrils into the fauces, and which are severally termed the inferior, the middle, and the superior meatus. Of these, the inferior is the largest, the longest, and the most direct, leading horizontally backwards to the throat. The middle is smaller, but nearly as long. The superior is much shorter, narrower, and more oblique. These canals are so narrow, that a slight thickening of the membrane which lines them, is sufficient to impede the passage of the air, and sometimes wholly to obstruct it.

With the two superior meatuses, communicate several cavities hollowed out in the bones of the face. These are the *maxillary*, the *palatine*, the *sphenoidal*, and the *frontal sinuses*, and the *ethmoid cells*. The frontal and maxillary sinuses, and the anterior cells of the ethmoid bone, open into the middle meatus; and the sphenoidal, and palatine sinuses, and the posterior cells of the ethmoid, into the superior.

The nasal fossæ are lined by the pituitary or Schneiderian membrane, a thick, soft and spongy membrane, which adheres to the bones and cartilages of the nose. Its surface presents innumerable minute prominences, which, by some anatomists, have been considered as nervous papillæ; by others, as mucous crypts; but which Magendie regards, as composed of a tissue of vessels. The pituitary receives a great number of vessels and nerves. These nerves consist of the whole of the olfactory, or the first pair, and of a great number of filaments of the fifth, from the spheno-palatine ganglion, and from the nasal. The distribution of the olfactory nerve is not so extensive as that of the branches of the fifth pair. The former, after passing through the cribriform plate of the ethmoid bone, is distributed over the septum narium, and the surface of the upper turbinated bones; while the filaments derived from the fifth, are spread over the whole of the pituitary membrane. The sinuses, also, are lined with a thin, soft, delicate membrane, which adheres loosely to the walls of these cavities. It secretes the mucus which smears the pituitary membrane, and probably is useful in smelling. This membrane also receives some nervous filaments.

The sense of smelling is exercised during inspiration, the air, which is the vehicle of odours, being drawn into the nostrils, and passing through the nasal fossæ, on its route to the lungs, and perhaps depositing the odorous particles on the pituitary membrane, especially in those places where it receives the filaments of the olfactory nerves. As the superior part of the nasal fossæ is that on which the olfactory nerves are distributed, and where the air has to pass through the narrowest passage, it is here, probably, that the particles are arrested, and excite the sensation of smell. In the act of smelling, we generally shut the mouth, and contract the nostrils, and draw the air in forcibly; so that the

current of air is condensed, and its odorous particles concentrated and directed to the superior part of the nasal cavities.

The organ of smell differs from those of sight and hearing, in the circumstance that its general sensibility is blended with its peculiar sensibility, as an organ of specific sensation, in the same seat, the pituitary membrane; whereas, in the eye and ear, the two properties have separate seats, viz. the conjunctiva and the retina in the eye, and the auditory passage and the acoustic nerve, in the ear.* Like the nerves of vision and of hearing, the olfactory, according to Magendie, is insensible to contact, and mechanical irritation.

The general sensibility of the pituitary membrane is derived from the branches of the fifth pair distributed upon it; for in the four orders of vertebrated animals, the section of this nerve annihilates the sensibility of the membrane. From the moment that this nerve is divided, the pituitary membrane becomes insensible to contact, and to mechanical and chemical irritation; and, what is extraordinary, even to the most powerful and penetrating odours; from which it appears to follow, that though the olfactory is the peculiar nerve of smell, yet it cannot execute its functions as such without the aid of the fifth pair. Indeed, according to Magendie, the olfactory nerves are not essential to the perception of odours; for the destruction of these nerves in a dog was not found to produce an insensibility to *strong* odours; and they have been destroyed by disease in persons who have, nevertheless, enjoyed the powers of the sense to the last moments of life; while the destruction of the fifth pair by disease has been found entirely to abolish the sense of smell, as well as the common sensibility of the pituitary membrane.

The nose appears to be necessary to the sense of smell. The use of it seems to be, to direct the air, loaded with odorous particles, to the superior part of the nasal fossæ. The loss of it, by accident or disease, is said to be followed by the abolition of the sense; which, however, may be restored by the construction of an artificial nose.

The uses of the sinuses are not fully ascertained. They do not appear to be endued with sensibility to odours; for neither the injection of odoriferous substances into them, nor exposing them to odorous effluvia, in persons affected with fistulous openings into these cavities, has been found to excite the sensation of smell. According to Magendie, the only known use of them is to furnish a part of the nasal mucus. There appears, however, to be a connexion between the capacity of these sinuses and the acuteness of the smell, in the inferior animals, those which have the largest sinuses enjoying the sense in the greatest perfection.

* Magendie.

An animal may be deprived of smell by making an opening into the trachea. Bourdon remarks that those persons who are unable to pronounce the letters *m* and *n*, generally have the sense of smell imperfect.

CHAPTER XXVI.

TASTE.

Taste is the sensation excited by the impression of certain substances upon the organs of taste, particularly the tongue.

The apparatus of taste consists of the tongue, which is its principal organ, the palate, the internal surface of the cheeks, the teeth, the velum pendulum, and the pharynx; all of which parts are susceptible of impressions of taste from the contact of sapid bodies. The superior surface of the tongue, however, is the principal seat of this sense, as will appear upon moving a sapid substance, as a piece of sugar or salt, over different parts of the mucous membrane which lines the mouth; for no sensation of taste will be excited, except when the substance is applied to the superior surface of the tongue. Yet if a little sugar or salt be placed *under* the tongue, and the latter then be pressed against the floor of the mouth, the taste of the sugar or salt will be distinctly perceived. That the tongue, however, is not the exclusive seat of taste, appears from the fact, that examples of a total loss of the tongue, and even of a congenital deficiency of it, have occurred without being accompanied with a loss or absence of the sense.

The tongue is an organ of extraordinary mobility, extending from the incisor teeth, with which its apex is in contact, backwards to the os hyoides, and the epiglottis, to which its root is attached. It is composed of muscles, which constitute most of its substance, of glands, nerves, blood-vessels, and absorbents, covered by a mucous membrane. This membrane possesses two kinds of sensibility, the one general, the other special, or, that by which it is susceptible to impressions from sapid substances. Its cuticle, or epithelium, is very thin; its corpus mucosum thick and moist; and the cutis vera gives rise to the *papillæ* of the tongue. These are divided into three series, according to their magnitude, viz. the *conical*, the *fungiform*, and the *lenticular*. This last series of glands are the largest, and are disposed nearly in the form of a right angle, near the root of the tongue, with

the apex towards the pharynx. The others, of different magnitudes, are disposed promiscuously over the superior surface of the tongue, chiefly at its edges and apex, where the taste is most acute. These last appear to be formed of a vascular and nervous tissue, susceptible of erection.

The nerves of the tongue are derived from four different sources. It receives; 1. Several filaments from the spheno-palatine ganglion, especially the naso-palatine. 2. The glosso-pharyngeal. 3. The hypoglossal. 4. The lingual branch of the fifth pair. Magendie denies that any of the nerves of the tongue can be traced into the papillæ of the organ.

The twigs derived from the spheno-palatine ganglions are supposed to preside over the nutrition and the secretions of the organ; the glosso-pharyngeal to be the source of the general sensibility of the tongue and pharynx, and of their motility, as associated in deglutition; the hypoglossal as presiding over the proper motions of the tongue; and the gustatory as the source of its specific sensibility to tastes. The branches of this last-mentioned nerve are distributed, not only to the muscles and mucous surface of the tongue, but also to some of the salivary glands; and in this manner they connect the sensations of taste with the secretion of the salivary fluid.

The functions severally ascribed to these nerves, have been partly determined by experiment. Thus, Magendie states that if the gustatory nerve be divided in an animal, the tongue continues to move, but is no longer sensible to the impression of sapid bodies; yet the palate, the gums, and the internal surface of the cheeks, still preserve their general sensibility. But if the trunk of the fifth pair be divided in the cranium, the power of being affected by sapid bodies, even the most acrid and caustic, is entirely abolished in the tongue, lips, cheeks, teeth, gums, and palate. This total abolition of taste also occurs in persons in whom the trunk of the fifth pair is compressed or altered by disease. In the sense of taste, Magendie remarks, general sensibility is confounded with special; and both properties are evidently derived from the same nerve, the fifth pair.

The experiments of Professor Panizza, of Pavia, however, upon the nerves of the tongue, favour the conclusion that the sense of taste is not derived from the gustatory or lingual branch of the fifth pair, and that general and special sensibility are not confounded together in the tongue, as Magendie imagines. The excision of a portion of each lingual nerve in a dog was followed by a complete annihilation of all sense of feeling in the tongue, while motion and taste both remained. The animal readily lapped milk, and ate bread or flesh presented to him; but if a bitter taste were given to the milk or the solid food by the addition of a little colocynth, or infusion of quassia, the dog, though

he had previously evinced a strong desire for the food, after taking a mouthful of either immediately refused both. Even when a feather slightly moistened in the bitter fluid was drawn lightly over the dorsum of the tongue, the dog still discovered strong marks of disgust. That feeling was abolished was evident, because severe injuries to the tongue, as deep incisions, and even the cautery, excited no pain.

But upon dividing the glosso-pharyngeal nerves, the dog ate and drank readily, but appeared to have no other guide in the choice of his food than the sense of smell, for he devoured with indiscriminate voracity both plain flesh and milk, and that which had been rendered bitter with colocynth. And he not only devoured a piece of meat which had been beaten up with colocynth, but even lapped up the remainder of the liquid in the plate. In one of these experiments, a dog, whose glosso-pharyngeal nerves had been divided, readily devoured a piece of meat, flavoured with colocynth, which had been rejected with loathing, and even vomiting, by another dog in which the lingual nerves had been divided.

From these experiments, then, it should seem that the glosso-pharyngeal nerve, and not the lingual branches of the fifth pair, preside over the sense of taste. But it also appeared that general sensibility in the tongue is derived from the branches of the fifth pair; for on pricking the tongue after the section of the glosso-pharyngeal, the dog howled, and attempted to run away.

The experiments of Panizza on the lingual nerves appear manifestly to contradict those of Magendie. It will be observed, however, that Magendie's assertion refers to the division of the trunk of the fifth pair in the cranium, which he says entirely abolishes the sense of taste in the tongue, lips, cheeks, teeth, and gums; whereas in the experiments of the Italian physiologist, the two lingual branches only of the fifth pair were divided.

In confirmation of his views, Panizza remarks, that the glosso-pharyngeal nerve, both in man and other animals, without giving a single filament to the muscles through which it passes, is wholly distributed to the mucous membrane of the tongue and neighbouring parts, which are endued with the sense of taste; and that this sense is most acute in the place which is most abundantly supplied with filaments from this nerve, i. e. towards the base of the tongue.

Magendie's idea of a fusion of the two kinds of sensation, general and special, in the organs of taste, both being derived from the trigeminal nerve, is contradicted by an interesting pathological case, in which acute gustatory sensibility existed in one side of the tongue, in which common sensibility was almost wholly abolished. The patient was affected with a paralysis of sensation on the left side of the head and face, and amaurosis of

the left eye, the power of voluntary motion remaining unimpaired. The left half of the tongue participated in the affection, and was insensible to impressions of touch, even of a painful kind, to roughness, smoothness, heat and cold, &c.; but to sapid impressions, as bitter, sweet, and other modifications of taste, the affected side of the tongue was as acutely sensible as the sound. From various experiments, it appeared that while common sensation was annihilated in one half of the tongue, the sense of taste remained unimpaired. Further researches on this subject appear to be necessary.

Pinching the hypoglossal nerve in an animal, immediately after death, occasions convulsions of the muscles of the tongue; while pinching the gustatory is not followed by contractions of these muscles.

The glosso-pharyngeal is distributed to the roots of the tongue and the upper part of the pharynx. According to Mayo, the twigs sent to the root of the tongue are nerves of sensation only; while those distributed to the upper part of the pharynx are subservient both to sensation and motion. The tongue is the principal organ of taste, but the sense exists in various degrees in different parts of the organ. In general, the sense is most acute at the tip and edges of the tongue, and least so at its root. Sour and sweet tastes are most sensibly perceived by the apex of the organ; and bitter and alkaline ones by its root. The root is also the principal seat of the *after-taste*, which some substances leave in the mouth. In exercising its functions as the organ of taste, the tongue is in an active state. In fact, motion of the tongue is as indispensable to taste as motion of the fingers is to all the delicate perceptions of touch. In both of these classes of sensations, the respective organs are active and in motion, and they are scarcely sensible to their appropriate impressions, if made upon them when they are in a wholly passive or quiescent state. The tongue explores by various motions the sapid qualities of substances applied to it, exactly as the fingers explore by motion the tactile properties of bodies. The muscular and sensitive nerves of these organs of sense concentrate their functions upon these perceptions, which require the aid of both, and which, from this concurrence, may sometimes appear to depend chiefly on one class of nerves, and sometimes on the other. It is partly from this cause, that Brown ascribes to muscular contraction many of the perceptions which have been usually ascribed to touch.

It is also worthy of remark, that we can never taste well without bringing those parts of the tongue on which the impressions are made into contact with the neighbouring parts of the mouth. Though the tongue is the principal organ of taste, we can taste very imperfectly with the tongue alone. In order to exercise

the sense perfectly, we apply the dorsum of the tongue to the palate, or its tip to the palate or the lips.

Raspail remarks, that for the tongue to perceive savours, it must be placed in communication with some other part, or even with a foreign substance, by means of the sapid body. Thus, if we dip the end of the tongue in a sapid liquid, we experience merely a sensation of touch, but none of taste. But if we now apply the end of the tongue to a silver spoon, the perception of taste, he says, is immediately developed. So if we moisten with a little syrup the lips, gums, teeth, or palate, no perception of taste will be excited in these parts; but if we now apply the tip or edges of the tongue to the moistened part, we shall immediately perceive the taste of the syrup. Hence, Raspail considers the tongue alone as the proper seat of taste; but for the production of the sensation two other factors are necessary, viz. a sapid substance, and a third body, with which the tongue is brought into communication by means of the former. The process he regards as a galvanic one; the tongue representing the positive pole, the palate, cheeks, lips, teeth, &c., the negative, and the sapid body, which must be in a fluid state, as completing the circle. Raspail illustrates this view by the well-known experiment of placing the end of the tongue between two pieces of coin, one of silver, the other of copper or gold. When in this position, if the edges of the two coins are brought together, an acid taste is perceived at the instant of contact, but disappears the moment this is interrupted. The perception of taste in all other cases, he maintains, is the result of a similar mechanism, and the tongue by itself, he says, is incapable of tasting any thing.

Different kinds of sapid substances affect different parts of the mouth. Some, for example, act chiefly upon the tongue; some upon the gums; some upon the palate, the pharynx, &c., others, upon the teeth. The teeth possess a peculiar sensibility to certain sapid substances; a fact which, we are informed by Magendie, was ascertained by Miel, a dentist of Paris, to be owing to imbibition. Miel demonstrated that the teeth rapidly imbibe liquids which come into contact with them, and which thus penetrate into the central cavities of the teeth, where their nerves are lodged. The *after-taste* left by many substances in the mouth, in like manner affects different parts of this cavity. Thus, acrid substances leave an impression on the pharynx; acids, upon the lips and teeth, &c. There are several substances, which, besides exciting the sensation of taste on the tongue, are capable of producing a different impression, which is usually referred to the palate, but in reality has its seat in the nasal cavities. These substances, when under the action of the jaws, emit some of their volatile particles, which, during deglutition, ascend into the pos-

terior nares, and excite sensations which belong, not to the taste, but to the smell. These sensations constitute a great part of the *flavour* of sapid substances; and by closing the nostrils during deglutition, it is easy to ascertain how much belongs to each sense.

Sapid substances, in order to excite the sensation of taste, must either be dissolved before they are received into the mouth, or they must undergo a solution in the saliva. This remark, of course, does not apply to liquids and gases.

The sense of taste is subservient to digestion, as that of smell is to respiration. The developement of it in the mammiferous animals and in man, is said to be, with few exceptions, in proportion to their voracity, and their degradation in the scale of intelligence. Of all the senses it is the most sensual.

CHAPTER XXVII.

MOTION.

The motions of the human body are extremely numerous, various in their kinds, and executed by different kinds of structure. They are generally divided into voluntary and involuntary, or those which are performed under the control of the will, and such as are wholly independent of this power. The voluntary motions are all executed by organs, which are called muscles, and which are animated by nerves, originating in the cerebro-spinal system. Such are the motions of the limbs and trunk of the body; those of the face, of the eyeball, of the tongue, of the velum pendulum palati, of the pharynx, of the larynx, and glottis, and the motions of the diaphragm, the only voluntary motions which are not discontinued during sleep, and perhaps those of the bladder.

The involuntary motions are of two kinds. One class of them depend on the action of muscles, the other are executed by organs or tissues which are not muscular.

The first class of these motions, or those which depend on the action of muscles, comprehends the following, viz. the motions of the heart, of the œsophagus, stomach and intestines, and of the uterus. To these are added, by some physiologists, the motions of the iris. Over these motions the will has no direct influence. They receive their nerves, not directly from the brain or

spinal marrow, but by ganglions and plexuses, indirectly from both of these organs.

The involuntary motions which are not performed by muscles, comprise the following, viz. 1. The *vascular*, comprehending the contractions of the arteries, dilated by the blood forced into them by the heart; the motions of the capillary vessels of all kinds, nutritive, secretory, &c. and those of the lymphatic vessels; the motions of the vesiculæ seminales, of the spermatic ducts, of the excretory ducts, of the liver and gall-bladder, and of those of other glands. 2. The *membranous*, including the motions of the skin, which frequently contracts, or shrinks, under the influence of cold, of terror, of gastric sympathy; the vermicular motion of the scrotum, from cold or other causes. 3. The motions of expansion of the erectile organs and tissues; as the organs of generation, the papillæ of the tongue, the female breasts and nipple, the lips, the ends of the fingers; and certain accidental tissues, as aneurism by anastomosis. To this class of motions, those of the iris are referred by some physiologists.

To these kinds of motion may be added another, viz. communicated motions, as those of the bones, and of other passive organs; those of the brain and spinal marrow, by the action of the heart; the motions of the abdominal viscera, from the action of the diaphragm and abdominal muscles; the motion of the blood by the action of the heart; and of other fluids by the action of their respective vessels or reservoirs, and by the contraction of neighbouring muscles.

Muscular Motion.

Muscles are fleshy organs, composed of reddish, wrinkled fibres, united together by cellular tissue into bundles, progressively increasing in size, and the organs thus formed, terminating at both extremities by a fibrous, inert structure, by which they are attached to the bones.

These organs may be resolved into fasciculi, or bundles of muscular fibres, each inclosed in its proper sheath of cellular tissue; the primitive fasciculi may be divided into secondary, and these again into smaller bundles, until at last we reach the ultimate muscular filament, beyond which the analysis cannot be pursued. Each of these fasciculi has its own sheath of cellular tissue, which serves at the same time, to connect it with those nearest to it. The whole organ, also, has a common sheath of the same tissue.

The size of the primitive muscular filament it is difficult to estimate. According to some physiologists, they are so fine, that if hollow, they could not transmit the forty-sixth part of a red globule of blood; but, according to Mr. Bauer's observations,

their size comes more within the limits of our comprehension. He states, that the globules of blood, when deprived of their colouring matter, and examined by a high magnifying power, appeared to be of the same diameter as the ultimate muscular fibre; and he even supposed he had discovered that the filament was in fact, composed of a series of globules, disposed in straight lines. The size of the globules, and of course, the diameter of the ultimate filament, he estimates at about one two-thousandth of an inch. Beclard, Prevost and Dumas, are of the same opinion. Other physiologists, however, differ widely from this opinion. On the whole, the subject is in a very unsettled state. The fibres, it is said, whatever may be their diameter, have the same size and the same form in all the muscles.

The muscles are plentifully supplied with blood-vessels, which are distributed among the muscular fibres in numerous ramifications, and forming frequent anastomoses. They are also furnished with lymphatics, and with a large apparatus of nerves, which the muscles of voluntary motion receive from the brain or the spinal marrow.

The muscular fibre is composed almost wholly of the fibrin of the blood; a proximate element, which abounds in azote. By the action of the nitric acid upon it, a large quantity of azote and carbonic acid is extricated, and a peculiar fatty substance is formed, which has received the name of *adipocire.* The same change is produced when large numbers of human bodies have been buried promiscuously in pits; and also by the action of running water upon muscular flesh.

The properties of the muscles are of two kinds; one is *contractility of tissue,* or *animal elasticity,* a property which they derive from the large quantity of cellular tissue incorporated in their substance; the other is *muscular contractility,* or *myotility,* a property peculiar to the muscular fibre. By virtue of the former property, muscular parts are susceptible of considerable distention, and capable of recovering their previous dimensions after the distending cause is removed. When any part of the body is moved, the antagonist muscles of the part are put on the stretch. All flexion calls into action the elasticity of the extensors, and *vice versâ.* This property is particularly exhibited in the muscles which do not act under the influence of the will; as in the hollow viscera, the stomach, intestines, and uterus, which are capable of very great distention in consequence of the presence of this property in their membranous coats. The same property is also displayed in tumours, in the distention of the abdomen, from pregnancy, or ascites, &c. When a muscle has been subjected to distention, and the distending power is afterwards removed, it gradually recovers its previous dimensions, as appears in the reduction of the abdomen to its natural size after the evacua-

tion of the water in ascites, and after parturition, and in the shrinking of a part to its original dimensions after the discharge of an abscess, or the removal of a tumour. The same property occasions the retraction of the two parts of a divided muscle; and Bichat ascribes to it the attitudes which the limbs assume when they are not influenced by any muscular contraction. When the vital contractility of the muscles is not exerted, the extensors and flexors mutually balance each other by their contractility of tissue. When a muscle contracts by an exertion of its myotility or vital contractility, it has to overcome the contractility of tissue of its antagonist; and when the vital power ceases to act upon the former, the contractility of tissue of the muscle thus put on the stretch enables it to return to its former dimensions. Hence, when a muscle is divided, besides the spontaneous retraction of its two parts, the contractility of tissue of its antagonist, being no longer counteracted, tends still further to increase the separation. It is worthy of notice, that the two portions which have thus retracted, will shorten still more if subjected to irritation, and afterwards become elongated to their last dimensions. The muscles owe this property of retracting chiefly to the large quantity of cellular tissue incorporated in them; but probably the muscular fibre itself is not wholly devoid of it.

But the distinguishing property of the muscular fibre is its *myotility* or *irritability*, or, the vital power of contracting or shortening itself on the application of a stimulus. In the act of contraction, the two extremities of the muscle approximate, its belly swells, and becomes hard and firm to the touch; its surface furrowed and drawn into wrinkles; and the whole muscle thicker and shorter. During the contraction, the fibres are agitated with a continual motion, arising from the contraction of some and the relaxation of others of them; for though the whole organ shortens itself during its contraction, this is not the case with all its fibres; these do not all contract at the same time. This continual agitation of the fibres during the contraction of a muscle gives rise to a perceptible sound, which may be heard by the aid of a stethoscope, or by applying a finger forcibly to the external auditory canal. This effect becomes more striking by applying to the ear the hollow of the hand, with the muscles in a state of relaxation, when scarcely any sound will be perceived; but if now, without altering the position of the hand, we put all its muscles in a state of strong contraction, a loud buzzing or vibratory sound will immediately be heard. The sound heard on applying a conch-shell to the ear, is said to be owing to the same cause.

During their contraction, the muscular fibres which, during the inaction of the muscle, preserved a rectilinear direction, bend themselves in a zigzag form, presenting regular undulations; and, according to Prevost and Dumas, the summits of the angles

thus formed, are the points of the muscular fibre where the ultimate divisions of the nerves which penetrate the muscles at right angles pass into them.

Many distinguished physiologists are of opinion that a muscle, in contracting, experiences no change of volume. Prevost and Dumas, Blane, Bourdon, Soëmmering, Meckel, &c., are of this opinion. They believe that the swelling of the belly of the muscle, is exactly compensated by the shortening of the organ.

Some delicate experiments of Glisson, of Swammerdam, of Erman, and Gruithuisen, however, if their accuracy can be depended upon, appear to establish the contrary conclusion. Glisson procured a wide cylindrical glass tube, closed at the bottom, and having a small funnel-shaped tube inserted into it near the top. Into the opening of the large tube, the whole naked arm of a strong, muscular man was introduced, and the mouth of the tube was then closed around it. Water was then poured into the small tube, until it filled all the space round the arm, in the large tube, and stood at a certain height in the small one. Now when the man strained all the muscles of the arm, the water fell in the small tube; but rose again, when the muscles were relaxed. Rudolphi regards this experiment as perfectly satisfactory, notwithstanding the objections which Haller and others have brought against it. Swammerdam, also, found that the contractions of a frog's heart, occasioned a sinking of the water in the small end of a thin glass tube, drawn out at one extremity.

In like manner, Erman and Gruithuisen found, that when a piece of an eel's tail, or of a frog's thigh, was introduced into a glass tube, provided with a small side tube, and was then subjected to the galvanic or electric shock, whenever the closure of the chain produced a muscular contraction of the part, the level of the water in the small tube was sensibly lowered.

According to Rudolphi, the few experiments in which no sinking of the water has been observed during the contraction of muscles, have been too coarse and inaccurate to warrant any conclusion. The essence of muscular contraction he supposes to consist in a condensation of the muscular substance, by which it contracts on all sides.

By other physiologists, the diminution of the volume which a contracted muscle experiences, admitting the reality of the phenomenon, is ascribed to the compression of the cellular tissue, to the pressing out of the venous blood of the muscle, and the obstruction occasioned by the contraction of the muscle to the entrance of arterial blood.

A muscle is able to preserve a state of contraction only a limited time. Sooner or later the effect ceases, and the muscle returns to its former state, or becomes relaxed. It is assisted,

probably, in recovering its former dimensions by the power of its antagonists. The duration of the contraction is different, according as it is excited naturally, or artificially. When excited by an act of the will, the contraction can be continued for a considerable time; but the effort at last becomes painful and difficult, and can no longer be maintained. When the voluntary muscles contract under the influence of morbid irritation, the the contraction is sometimes of a permament kind, as in tetanus, and trismus. But if a muscle be exposed to direct irritation of a mechanical kind, or to galvanism, the contraction is soon followed by relaxation, though the application of the stimulus be continued.

The velocity of muscular contraction produced by an act of the will is very variable, and is regulated by volition. The possible celerity of muscular action depends much on exercise, and may be almost indefinitely increased by practice. Haller computed, that the elevation of the leg of a race horse, in the act of racing, is performed in the one-seventieth part of a second. He also calculated that in the most rapid motions of a man, the *rectus femoris* is shortened three inches, in the two hundred and eightieth part of a second. But he remarks, that the muscles employed in articulation, execute the most rapid contractions. He states that he himself pronounced fifteen hundred letters in a minute; a task of little difficulty, as any one will find, who will undertake it.

A muscular fibre in a state of strong contraction, is from one-fourth to one-third shorter than when in a state of relaxation. The degree of shortening appears to be in the ratio of the length of the fibre, and the degree of its contractile energy.

The power of muscular contraction is very great, though it is difficult to appreciate it. The effects produced by muscular contraction are sometimes very extraordinary. The extensors of the knee have been known to fracture the patella, by a sudden and violent contraction during the operation of lithotomy. The same accident has taken place during a fall, in consequence of a sudden and violent contraction of the extensor and flexor muscles simultaneously, as if the mind in its terror and confusion, had issued orders for both sets of muscles to contract at the same instant. Some of the feats performed by itinerant gymnasts display astonishing strength, such as taking up a smith's anvil by the teeth, and throwing it over the head. Rudolphi mentions a fact, which may illustrate the great force of muscular contraction, even in feeble persons, when excited by morbid irritation. It was a case of chorea, occurring in a girl, twelve years of age. In an attack of opisthotonos which she experienced, several grown men stood on her abdomen, to counteract the curvature of the body, produced by the spasms, but without the least effect.

If a person with a burden on his back, stands on tiptoe on one

foot, the whole weight of the body, and of the burden, is supported by the extensor muscles of the foot. In jumping, these muscles project the body with immense force.

The power of muscular contraction depends, partly on the organization of the muscles, particularly the volume and number of their fibres, and partly on the degree of the excitation which they receive, or the force of the stimulus which acts upon them. The influence of the brain has a great effect in increasing the energy of muscular contraction. The degree of power exerted in the voluntary motions, depends in general on the will, which adapts it exactly to the effect intended to be produced. If we merely raise the arm, or elevate a very small, or a very heavy weight, the force of the muscular contraction is precisely adequate to the effect. When the brain is excited to preternatural energy, by causes foreign to the will, as in maniacs, in persons transported with passion, and in the delirium of fever, the power exerted by the muscles, even in persons of a feeble or delicate organization, is sometimes very great. The excitability of the nervous power, and the strength of the muscular organization, are frequently in the inverse ratio to each other. Women and children who have comparatively feeble muscles, possess very excitable nervous systems; and, on the contrary, brawny and athletic men, having strongly marked, prominent muscles, frequently possess but little nervous excitability.

The strength of a muscle is much greater in a living state, than after death. A dead muscle will be lacerated by a much smaller weight appended to it, than the muscle could lift with ease during life. The muscular part of a dead muscle is torn through by a less weight than the tendinous. But, in the living state, it is the tendon which is the first to give way. Thus, the tendo achillis is sometimes ruptured by the force exerted by the muscular fibres of the gastrocnemii, and soleus muscles.

The power of contraction of the muscles is much weakened by want of sleep, by fatigue, excessive heat, evacuations, and the abuse of stimulants, especially alcoholic drinks and opium. Even a moderate draught of wine will frequently produce a feeling of weakness in the muscles, and very sensibly impair their powers of exertion. On the other hand, the muscular power is recruited by rest, sleep, plain food, and bathing. The muscles of voluntary action, like the other organs of animal life, are subject to a complete periodical rest every twenty-four hours.

The phenomena of muscular contraction require certain conditions, without which they do not take place. These are the action of some stimulant or excitant, without which the muscle remains in a state of relaxation; the presence of vitality in the muscle; the integrity of its organization; and the uninterrupted communication of its vessels and nerves with the centres of the

circulating and nervous systems. Without the influence of some excitant, the muscles remain without contraction. The excitants which may rouse a muscle to action, are of different kinds, as, for example, *the will;* certain stimulants, applied directly to them, or to the nervous centres with which they communicate, or to the nerves which form the channel of communication. A muscle deprived of its supply of arterial blood, contracts very feebly. If its communication with a nervous centre be interrupted, it is withdrawn from the influence of this centre; and if irritations, applied directly to it, excite contraction in it, it is because they act upon its inherent irritability, or upon the nerves incorporated in its substance. The irritability of a muscle is generally diminished by extreme cold or excessive heat, by the direct application of opium and some other substances to it, and by over-distention.

It is remarked above, that the presence of vitality is a necessary condition of muscular contraction. It is to be observed, however, that certain of the muscles, both voluntary and involuntary, in some instances continue to act some time after death. This is true particularly of the heart and intestinal canal; but nearly all of them may be excited to contraction by artificial means. In the amphibia especially, as the frog and the salamander, the muscular irritability continues a long time after death. In birds, on the contrary, the irritability of the muscles is very soon extinguished, ceasing much earlier than in the mammalia and the human species.

According to Nysten, the duration of the contractility of the muscles after death, in the different classes and orders of animals, is in the inverse ratio to the degree of energy with which the muscles are endued during life. To this principle, however, there are many exceptions.

Some of the muscles lose their contractility much sooner than others; and, according to the same physiologist, the order in which this property becomes extinguished after death, in different muscles in the human body, is as follows:

1. The left ventricle of the heart loses it first.
2. The stomach and intestines next; the large intestines, from forty-five to fifty-five minutes after death; the small intestines, a few minutes later; and soon after, the stomach.
3. The urinary bladder, which sometimes loses its irritability as soon as the stomach, but frequently somewhat later.
4. The right ventricle of the heart, whose motions in general continue more than an hour after death.
5. The œsophagus, which ceases to contract about an hour and a half after death.
6. The iris, whose irritability is extinguished in many cases, fifteen minutes later than that of the œsophagus.

7. The muscles of animal life. In general, the muscles of the trunk lose their contractility sooner than those of the limbs; and the muscles of the lower limbs earlier than those of the superior.

8. The auricles of the heart. But the right auricle loses the power last; so that of all parts of the heart, it retains its contractility the longest. The right auricle is therefore truly the *ultimum moriens*, as it was called by Galen and Harvey. In experiments on dogs, it was frequently found that the *left ventricle* lost its irritability in half an hour after death; while that of the *right auricle* continued eight hours.

The venæ cavæ, where they join the right auricle, are evidently muscular, and are irritable like the muscles themselves. No contraction can be perceived in the arteries by the application of a stimulus. The muscles usually become rigid after death, a phenomenon which is the effect of their last contractile effort. It occurs sooner or later according to circumstances; and its duration also is very variable. In persons killed by lightning, the muscles are said not to become rigid after death. In animals hunted to death, or over-driven, the muscles stiffen in a few minutes after death; but the rigidity is not great, and is of shorter duration than in other cases. In hot weather, the muscles of slaughtered animals never become very rigid. Mayo remarks that warm water injected into the arteries of a muscle, will instantly cause them to become rigid, the flesh becoming pale, increased in volume, and suddenly hardening.

The stimuli which produce vital contraction of the muscular fibre, are of various kinds. The muscles belonging to animal life, or those of voluntary motion, contract under the influence of the will, or by the energy of the brain, acting through the medium of the nerves. But there are also certain pathological causes, by which the brain may be excited to react upon the muscles of voluntary motion without the intervention of the will. Such are local irritations acting directly upon the brain; as for example, local injuries, morbid determinations of blood, inflammation of the organ, preternatural excitement of the brain, from insanity, violent passions, &c. In other cases the brain may be excited by sympathy with some other suffering organ, and react upon the voluntary muscles, producing involuntary contractions, or convulsions. Intestinal irritation from worms and other causes, and uterine irritation, may thus indirectly give rise to spasms of the voluntary muscles.

In general, the energy of muscular contraction is increased by causes which excite the brain, as wine, opium, passion; and on the other hand, it is diminished by causes which exert a sedative influence over the cerebral energy, as terror, which may induce an almost paralytic weakness.

The energy of the brain is transmitted to the voluntary muscles

by the medulla spinalis and nerves; and irritations applied to the spinal cord, influence the muscles which receive their nerves below the affected point, precisely like irritations applied to the brain. Irritation of this column of nervous matter excites convulsions, and compression of it produces paralysis of the muscles. The higher up the spine the injury is inflicted, the greater is the number of muscles affected, and the greater is the danger to life. If the lumbar portion of the spinal marrow be injured, the muscles of the pelvis and of the lower limbs become paralysed. If the dorsal portion be injured, those of the abdomen are affected, and respiration begins to be embarrassed. If the spinal cord be injured above the origin of the phrenic nerves, the diaphragm is paralysed, and respiration immediately ceases. Irritation of the nerves by mechanical or chemical agents, causes involuntary contraction of the muscles supplied by these nerves, and when several muscles are supplied by a single nerve, irritation of this nerve will convulse them all. So, if a nerve be compressed or divided, the muscles supplied by it will no longer contract under the influence of the will. They will become paralysed, not from a loss of their proper irritability, but from the absence of its usual excitant. For they may still be stimulated to contraction by some irritation applied directly to them.

It appears, therefore, that the proper stimulus of the voluntary muscles is, the energy of the brain, which may be determined by one of three causes: 1. an act of the will, which is the usual and natural excitant; 2. some impression made upon the brain independently of the will; and 3. sympathy with some other organ, as the alimentary canal, or uterus, affected with morbid irritation. In the two last cases, not only is an act of the will unnecessary to produce the muscular contraction, but it is also wholly unavailing to prevent it. A healthy action of the nerves is also necessary to the effect; and irritation of these organs will produce involuntary contractions of the muscles, precisely like irritation applied to the brain or the spinal cord.

A physiological state of the muscles themselves is necessary to their contraction. If these organs be inflamed, bruised, or excessively distended, they are unable to contract. A due supply of arterial blood is also necessary. If venous instead of arterial blood be transmitted to them, it renders them incapable of executing their functions.

It has been discovered, that in several animals remarkable for the slowness of their motions, the principal artery in each limb abruptly divides into several trunks, which run in a parallel direction, and freely anastomose with one another. In the foreleg of the lemur tardigradus, there are sixty brachial arteries formed in this manner. A consequence of this disposition must be a diminished impulse of the blood circulating in the muscles

of the limb; but what connexion this may have with the exceeding sluggishness of the movements of this animal, it is not easy to conjecture.

But other causes besides the influence of the brain and nervous system, may excite contractions of the voluntary muscles. Thus, mechanical and chemical stimuli of various kinds, applied directly to them, as pricking or cutting them, &c., the application of acids, alkalies, electricity, galvanism, will excite them to contract. If a muscle be laid bare in a living animal, it contracts with a kind of tremulous motion. The same effect is produced, if a muscle be wholly removed from its connexion with the living parts of an animal, and subjected to irritation. It is not necessary to irritate the whole mass in order to produce the effect; for the irritation of a few fibres, by a puncture, is sufficient to excite contraction in the whole organ. If a ligature be applied to the blood-vessels of a muscle, the organ in a few moments becomes completely insensible to galvanic irritation.

It is a *vexata quæstio* in physiology, whether the muscles derive their power of contraction from the nerves, which are incorporated in them, or whether their irritability is an inherent and specific property of the muscular fibre. Haller contended for the latter opinion, and accordingly termed this property the *vis insita*, and the *vis musculorum propria;* while many distinguished physiologists have maintained the other. It is perhaps impossible to decide this question. But it seems probable that the muscular fibres and nerves are, both of them, factors of this power. It seems impossible that contractility of the muscles can be derived from the nerves, because the nerves possess no such power themselves. They cannot give what does not belong to them. But, on the other hand, as the muscles are universally supplied with nerves, and as it is impossible to conceive that any stimulus can be applied to a muscle without affecting some of the nerves incorporated in its substance, it is difficult not to suppose that the nerves are, in some mode or other, essential to the phenomena of muscular contraction. Any muscle may be excited to contraction by irritating the nerve which goes to it. It is true that a muscle, or part of one, even when removed from its connexion with the living body, is sometimes observed to contract; but it is to be remembered that a large quantity of nervous matter exists in it, and perhaps is essential to the phenomenon. Admitting the irritability of muscles to be an inherent and independent property, it is still true that all the muscles, without exception, require an influx of nervous power to excite them to contraction. This nervous power may be transmitted from the brain, or it may be directly excited by irritations applied to the nerves, or to the muscles themselves, when, undoubtedly, they act upon some of the nervous fibrils which are diffused throughout the substance

of the muscles. Tiedemann supposes that the nerves diffused throughout the substance of the muscles, impart to the latter a susceptibility to the action of their excitants, or the aptitude to be affected by them; or, that the stimuli which excite muscular contraction, act immediately upon the nerves distributed in the muscles, and produce the action of the latter only through the medium of these nerves.

The muscles of animal life, or those which act under the influence of the will, receive their nerves chiefly from the spinal marrow. These are the muscles which move the trunk and upper and lower extremities. Those which are chiefly designed to express the emotions of the mind, and may be considered as holding a higher rank in the scale of organization, receive their nerves directly from the brain. These are the muscles of the face and eyes.

The muscles of vegetative life, on the contrary, receive their nerves chiefly from the ganglionic system.

The essence, or immediate cause of muscular contraction, is unknown. Various hypotheses have been formed to explain it, but no knowledge is obtained by conjecture. One of the most ingenious and plausible theories which have been formed on the subject, is that of Prevost and Dumas, who regard muscular contraction as an electrical phenomenon; an opinion founded partly on microscopical observations. These physiologists first examined with a microscope the mode in which the nerves penetrate into the muscles, and are distributed in them; and they observed that the nervous filaments pierced the muscular fibres in a perpendicular direction, or at right angles to the axis of the fibres. They also took notice that no nervous filament actually terminated in the muscles, but that their ultimate ramifications embraced the muscular fibres, in the form of loops, and then returned to the trunks which had furnished them, or went to unite with some nervous trunk in the vicinity. Upon examining with the same microscope the muscles at the time of their contraction, they observed that the muscular fibres which composed them suddenly contracted, or bent themselves in a zigzag manner, and presented a great number of regular undulations; the angles of flexion varying according to the degree of contraction. These bendings, or angles, were observed always to take place at the same points in the muscular fibres, and to these flexions the contraction of the muscle was owing. They observed, finally, that the summits of these angles corresponded with the points where the nervous filaments entered the muscle. These observations led them to infer, that the shortening of the muscular fibres was owing to an attraction between the nervous filaments which entered them; the effect of which would be to approximate the points where these filaments entered the muscle, towards

each other, and thus to cause a wrinkling up, or contraction of the muscular fibres. The approximation of the parallel nervous filaments towards one another, they ascribed to a galvanic current passing through these filaments, in conformity to a law discovered by Ampere, that two galvanic currents, moving in the same direction, are attracted towards each other. This theory supposes what many physiologists of the present day are disposed to look upon as probable, viz. that the nervous influence is some modification of the galvanic fluid. Whenever a current of nervo-electric fluid is conveyed along a nervous trunk to a muscle, as it must enter the fibres of the latter in the same direction, by parallel nervous filaments, these filaments, according to the law of Ampere, will be attracted towards each other, and will draw the summits of the angles of flexion of the muscles towards one another, producing a shortening of the muscular fibres, in a zigzag form.

According to Raspail, the parietes of the ultimate cylinders are garnished with spiral filaments; and the shortening of the muscular fibre, or, in other words, the contraction of the muscle, is effected by the approximation of the coils of the spiral.

Most of the muscles of voluntary motion are long and slender, terminating at each extremity in tendinous cords, by which they are attached to the bones, on which they act, and which they move, in the manner of levers. The locomotive muscles, however, act under great mechanical disadvantages, in consequence of which there is a great expense of force to bring about an inconsiderable effect. These unfavourable circumstances, in the disposition of the muscles are chiefly two, viz. 1. That they are inserted into the bones near the centres of motion, while the weight they have to move is usually applied to the extremity of the lever. For the bones may be considered as levers, the joints as fulcra, or centres of motion, and the muscles as moving powers; and it will follow, from the laws of mechanics, that the nearer the attachment of the muscle is to the joint, or fulcrum, the less effect it will produce in moving the bone, and *vice versâ.*

It is inaccurate, however, to call this a loss of power. There is in fact no loss of power in the case; but a greater force must be applied to the short end of the lever in order to move the long extremity, because the latter, moving through a greater space, must move with a greater velocity than the short end; and, according to a well-known principle of mechanics, the forces on the two opposite ends of a lever will balance each other, if the one be as much greater than the other as its motion is slower. The opposing forces on the two ends of a lever are to each other, inversely, as their respective velocities, or distances, from the centre of motion. The object aimed at by this arrangement of the muscles was, to give to the extremities a great range and

freedom of motion, without making the limbs unwieldy or clumsy; and this object is perfectly attained by inserting the tendons of the muscles near to the joints, which are the fulcra, or pivots, on which the bones move. In the human arm, the deltoid muscle, by contracting less than an inch, raises the elbow twenty inches; and, of course, if it overcomes a resistance of fifty pounds, at the elbow, it must itself be acting with a force twenty times as great, or a force of one thousand pounds; this greater force, exerted by the moving power, being exactly compensated by the greater velocity and range of motion of the resistance overcome.

2. A second unfavourable circumstance under which the muscles act is, that they are attached to the bones at very acute angles, so that their line of action is very oblique. If they were inserted at right angles, then their whole force would be effectively exerted in moving the parts. If, on the other hand, they were exactly parallel to the bones to which they are attached, their whole force would be lost, and no motion of the bones would be produced by their contraction. The nearer the direction of the force approaches to a perpendicular to the lever, the greater will be the effect produced in moving the latter; and the nearer it approaches to a parallel, the greater will be the proportion of force expended without effect. In the human body, the line of action of the muscles forms a very acute angle with the bones which are moved by them; and in consequence of this unfavourable direction, there is a great loss of power.

The various attitudes and motions of the human body, are owing to the contractions of the voluntary muscles, acting upon the bones to which they are attached. The human body maintains the erect position by the powerful action of numerous muscles. If the body in an erect position be left to itself, and no muscular effort be made to sustain it, the head will incline towards the chest, the chest will flex itself on the pelvis, the pelvis on the thighs, the thighs on the legs, and finally, the legs on the feet. It is therefore necessary, in order to maintain an erect position, that the muscles of the back of the neck should support the head; the muscles of the back, the chest; the muscles of the loins and buttocks, the pelvis; those of the pelvis, the thighs; those of the thigh, the leg; and those of the calf of the leg, the foot. The attitude of standing, therefore, requires the action of a large part of the muscles of the body. It is further to be observed, that the equilibrium of the body is never perfect and steady. It is always more or less vacillating and unsteady. It is impossible to poise a dead body, supposing it to be rigidly extended, so exactly upon the two feet, as that it will retain an erect position. There is a constant *nisus* in the muscles of the body to keep it in such a position that the centre of gravity,

which is high, shall be constantly directly above the narrow base formed by the two feet and the space between them. To produce this effect, a constant change in the degree of action of different muscles is necessary.

The head is not poised exactly upon the spine, but its anterior part preponderates, so that it has a tendency to incline forward; and in order to counterbalance this tendency, several strong muscles are placed at the back of the neck, as the splenius, the complexus major and minor, the trapezius, and the posterior recti muscles. The action of these muscles, by tending to draw the head backward, counteracts the preponderance of its anterior part.

The spine, also, has a tendency to incline forward, partly in consequence of its having to support the weight of the head, which has the same inclination, and partly because, anteriorly, there are connected with it the thorax and abdomen, and the ponderous viscera contained in them, which powerfully increase the tendency to incline forward. To counterbalance this inclination there are several strong muscles, which occupy the vertebral fossæ, as the sacro-lumbalis, longissimus dorsi, multifidus spinæ, &c., muscles which extend from the sacrum to the inferior vertebræ, and from the inferior vertebræ to the superior. The fixed point of these muscles is below. The lumbar vertebræ are maintained in a straight position upon the sacrum, and when fixed, they become a point of support to those above, and so on successively from below upwards. Each vertebra is then a lever of the first kind, the power being at one end, viz. at the spinous or transverse apophyses, to which the muscles are attached; the resistance, consisting in the weight of the thorax and abdomen, being at the other, and the fulcrum between the two, at the articulation of the vertebræ.

The resistance acts upon a longer arm of the lever than the power, since the former is measured by the length of the ribs, and the latter by that of the spinous apophyses of the vertebræ. But this disadvantage is compensated by the circumstance that the muscles are inserted perpendicularly into the bones on which they act. Considering the vertebral column as a single lever, it may be referred to the third kind, in which the power is between the fulcrum and the resistance; and as it is at the inferior part of the spine that the power has the greatest resistance to sustain, since it has to support almost the whole length of the lever, it is here also that the muscles have the greatest thickness and strength, and the spinous and transverse processes are the largest.

The pelvis is immovably articulated with the sacrum, and of course no muscular effort is necessary to support these parts in their fixed position. But below, the pelvis rests upon the heads of the thigh bones, by the two cotyloid cavities. The pelvis

thus forming a single lever with the spine and the head, tends to fall forwards, partly in consequence of the tendency of all the superior parts of the body to incline in this direction, and partly from the oblique position of the pelvis. To counteract this inclination, several strong muscles contribute, as the glutæi muscles, the abductors of the thigh, &c., the action of which tends to keep the pelvis and the trunk in the same vertical line with the thigh. If the fixed point of these muscles is below, at their attachment to the thigh bone, their contraction must draw the pelvis and trunk backward, and thus counteract the inclination forwards of the superior part of the body. The trunk of the body, with the pelvis and head, may represent a lever of the third kind, the fulcrum being at one extremity, viz. the ileo-femoral articulation; the resistance, which consists in the weight of the trunk, at the other; and the power between the two, at that part of the pelvis to which the muscles are attached. As the lever is a long one, extending from the vertex to the acetabular cavities, a great force is requisite to overcome the resistance, and accordingly, the muscles destined to this office are very bulky and powerful, constituting the immense fleshy mass of the buttocks.

The thigh is articulated with the leg by too small a surface to poise the body upon without the aid of muscular action. From the structure of the femoro-tibial articulation, and the manner in which the pelvis presses upon the thigh bone, the lower extremity of the latter is forced forwards, flexing the leg upon the thigh. The extensors of the leg, the rectus femoris, and the triceps extensor cruris, counteract this tendency. Their lower extremity being attached to the tibia as a fixed point, and their superior to the upper part of the os femoris, they maintain the femur, and with it all the rest of the body, in the same vertical line with the tibia. These muscles also act upon a lever of the third kind. The fulcrum is at one extremity, viz. the tibio-femoral articulation; the resistance, which is the weight of the body, at the other; and the power is applied between them, at the place of insertion of the muscles.

The weight of the body and thighs is transmitted to the feet by the tibia. The superincumbent parts have a tendency to fall forwards, turning upon the ankle joint as a movable hinge; but they are supported by the muscles of the calf of the leg, viz. the gastrocnemii and soleus, the peroneal and the tibialis posticus, which have their fixed point in the feet. These muscles act upon a lever of the third kind; for the fulcrum is at one extremity, viz. the tibio-astragalar articulation; the resistance at the other, and the power between them, at the place of the superior attachment of the muscles.

The foot rests upon the ground by a surface of considerable extent, and is pressed firmly against it by the weight of the body,

and also adheres to it by the action of certain muscles, viz. the common and proper flexors of the toes. The contraction of these muscles tends to fix the toes firmly to the ground, and to give greater firmness to the position. The use of shoes destroys much of the effect of the action of these muscles.

Standing upon one foot is more difficult and much more fatiguing. The base of support is reduced to the dimensions of one foot alone, and the centre of gravity has a lateral inclination towards the unsupported side of the body. The muscles, whose action counteracts this inclination, are the glutæi, the gemelli, the tensor vaginæ, the obturators, the quadratus femoris, and the pyramidalis. Strong efforts of these muscles are necessary to maintain the line of gravity within the narrow dimensions of the base.

Walking. In man this is the most common kind of locomotion, and it consists in placing one foot before the other alternately, and carrying the body forward with it. In this kind of progression, the line of gravity is incessantly transferred from one of the lower extremities to the other, without the body being left a moment unsupported, as it is in jumping and running.

The mechanism of it is as follows: the person being supposed to be standing on the two feet, placed by the side of each other, he first inclines his body towards the left, so as to throw his weight upon the left leg. Then resting with his whole weight upon this leg, he bends the right, at its different joints, flexing the thigh upon the pelvis, and the leg upon the thigh, so as to shorten the limb and to detach it from the ground. Raising the right limb, he then advances it forward and applies it to the ground. At the same time he transfers the line of gravity of the body from the left leg to the right; and in doing so he moves the body obliquely forward and to the right, until its weight rests upon the right foot. At this moment the left leg is extended behind him, resting upon the toes. This in its turn is raised from the ground, and advanced forward of the right by a similar movement; and in this manner the motions of the two legs, carrying the body with them, alternate with each other as long as the progression continues.

Running is an accelerated progression, which in its mechanism is intermediate between walking and leaping. The lower extremities are advanced, one before the other alternately, as in walking, transmitting the weight from one to the other. But the limb which is left behind projects the body, as in leaping, to the other, which is in advance of it, so that the line of gravity is transported to the forward leg before the foot touches the ground, and for a moment the body is suspended, unsupported, in the air.

Jumping or *leaping*, is a rapid motion, in which the body is raised from the ground and projected to a certain height in the

air, and afterwards, by its own weight, falls to the ground again. In order to execute this motion, the person first bends all the articulations of the body, from the head to the feet, flexing the head forwards upon the neck, the spine upon the pelvis, the pelvis upon the thighs, the thighs upon the legs, the legs upon the feet, and the feet upon the toes; for the heel does not touch the ground. To this general flexion succeeds a sudden extension of all these joints, the effect of which, in consequence of the reaction of the ground, is to give a projectile motion to the body upwards and forwards, which overcomes its weight, and consequently raises it from the ground.

Springing or *jumping* with one foot is called *hopping.* The mechanism is the same as that of leaping, except it is performed by one foot only.

Swimming. This is a kind of springing or leaping in the water. The body being extended along the surface of the water, the lower extremities are flexed and drawn up towards the nates, and are then suddenly extended, as in the act of leaping. The water, forcibly struck by the feet, yields, in part, to the shock, but still resists and reacts against the body sufficiently to impel it forward with a force superior to its weight. The feet, which had been separated from each other in the act of extension, are then brought together again, in a line behind the body; and the hands in their turn are pushed outwards and backwards, describing two arcs of circles, cutting the water in their course, but experiencing resistance and reaction sufficient to aid in impelling the body forward. These motions of the hands and feet succeed each other alternately; and the body receives from them an impulse sufficient to counterbalance its own weight and keep it above water, and even to give it a pretty rapid motion forwards.

A remarkable fact with respect to the voluntary muscles, was ascertained by Mr. Hunter, viz. that these muscles after contracting to their utmost extent, might gradually acquire a new sphere of contraction. This fact was ascertained by the following case, mentioned by Mr. Abernethy. A lady, who had suffered a fracture of both knee-pans came to London many years after the accident, and consulted Mr. Hunter. After ascertaining that the union between the ends of the two patellæ was of an unyielding nature, he found that the muscles, attached to the patella were unable to move the retracted part, because they had already withdrawn it to the utmost extent of their original power. Hunter saw no reason why muscles so circumstanced might not acquire a new sphere of contraction, so as to be able to act upon the patella, and extend the leg. In order to put his ideas to the test, he had the patient placed in a sitting posture, upon a table, with her limbs hanging over it, and suffered to

dangle, like the pendulum of a clock. At first she was unable, by any exertion of the extensor muscles, to check the motion of flexion under the table, or to prolong or increase the motion of the limb in the opposite direction. But by practice she gradually acquired the power in a certain degree. Hunter then added weight to her limbs, to increase the demand for muscular exertion; and by degrees the patient at length recovered the power of extending the legs upon the thighs, and the ability to stand and walk.

It has already been observed that the muscular system may be divided into two great sections, differing from each other in their organization, vital properties, external form, and functions. In one of these, motion is produced under the influence of the will; in the other it is wholly independent of this power, and is determined by the application of peculiar stimuli. In some of the muscles these two characters are united. Hence, the muscles have been divided into voluntary, involuntary, and mixed.

Organic Muscles.

The muscular system of organic life, or the involuntary muscles, differ in many important particulars from the voluntary muscles, or those of animal life. They are by no means so extensively distributed over the body as the other class, and they constitute a much smaller portion of its bulk. These muscles are found principally in the chest, abdomen, and pelvis, forming a considerable portion of the hollow viscera contained in these cavities. In the thorax are the heart and œsophagus; in the abdomen, the alimentary canal; in the pelvis, the bladder. This system therefore exists principally in the interior of the body, removed from the action of external agents. No part of it, however, exists in the head.

The fibres of the muscles of animal life are arranged in straight lines. In those of organic life, on the contrary, the fibres are generally curved, so as to form cavities, or canals, of various shapes. These muscles are never attached to bones, nor do they terminate in tendons. They are never collected into insulated bundles of parallel fibres, like those of animal life, but they are generally arranged in thin membranous plates, forming broad muscular strata. The fibres are not disposed in a uniform direction, but decussate or cross one another, at various angles and in different directions. Hence is derived their power of closely embracing their contents, of contracting upon them, and even of obliterating their own cavities.

These muscles possess great animal elasticity, or extensibility and contractility of tissue; that is, they are susceptible of great distention by an accumulation of their contents, or from other

causes, and they have the power of recovering their former dimensions after the removal of the distending cause. Thus, the alimentary canal admits of great distention, from an accumulation of feculent matter, or the evolution of gas; and the urinary bladder, from great collection of urine. The bladder may be distended to three or four times its ordinary capacity, without losing its power of contracting. But, by excessive distention it is liable to become paralysed, in which case its muscular coat loses its power of contraction.

The chief seat of the elasticity of the hollow viscera is the cellular tissue, which enters largely into their structure. Perhaps the muscular fibre itself may possess this property in some degree.

The antagonists of the hollow muscles are their contents, and as long as they are distended by these, their contractility of tissue cannot be exerted; but when their contents are removed, they contract by this power into a small volume. It is to be observed, that the contents of the hollow viscera are not expelled from them by their contractility of tissue, (which merely enables them to resume their former dimensions,) but by their vital and muscular contractility, which produces the effect by a series of contractions and relaxations. When the muscular contractility of a hollow organ has expelled its contents, its elasticity enables it to contract to its former volume.

These muscles differ remarkably from the voluntary muscles, in the nature of the cause which excites them to contraction. Their peculiar stimulus is not the nervous or cerebral influence. They receive their nerves, not from the brain or spinal marrow, but from the ganglions; and the influence of the brain, whether determined by an act of the will, by impressions made directly on the organ, or by sympathy, exerts but little power over the contractions of these muscles. Every one is aware that the functions of organic life, the actions of the heart and arteries, those of the stomach and intestines, are not in the slightest degree influenced by the will; that they can neither be accelerated, nor retarded, nor suspended, by any effort of voluntary power. In like manner, irritation of the brain has no effect upon the action of these muscles. The circulation of the blood can be carried on without the aid of the brain, as is exemplified in the case of acephalous fœtuses; and it is well known, it can be kept up artificially after decapitation.

The peculiar stimuli of these muscles is that of their respective contents. Thus, the blood is the natural excitant of the heart and blood-vessels; alimentary and feculent matter, that of the stomach and intestines; the urine, that of the bladder, &c. They are also sensible, though in very different degrees, to artificial stimuli applied directly to them.

In general they are less sensible of the stimulus of galvanism than of mechanical irritation. And they are much less under the nervous influence than the muscles of voluntary motion.

Before leaving the subject of muscular action, it may not be improper to notice a curious fact, connected with it, which has not been generally known until recently, when the publication of Brewster's "Letters on Natural Magic" has at the same time given it publicity and an authentic shape. I allude to the experiment of raising a heavy person from the floor or from a table, in the following manner. The subject of the experiment lies down upon his back, and four persons, one at each shoulder and each leg, insert their hands under those respective parts and endeavour to raise him, which they find to be no easy task. At the next trial, at a signal given by a bystander, the subject of the experiment and the four lifters, take at the same time a long deep breath, and as soon as the act of inspiration is completed, another signal is given for repeating the effort, and to their great surprise, if the experiment is new to them, they find that the weight rises with the greatest facility, and they feel that with a little exertion they could toss the person to the ceiling. And it is truly remarkable, that if any one of the party fails to draw in his breath at the same time with the others, he will be seen tugging away at his share of the weight, which he raises with difficulty from the floor, while the three other parts are already in the air. This experiment I have repeatedly seen, and have assisted in performing, and of the reality of the facts I am fully convinced. That they involve no little difficulty to the physiologist or natural philosopher will be readily granted, when even Brewster calls them inexplicable.

CHAPTER XXVIII.

OF THE VOICE.

The organ of the voice is the larynx, a cartilaginous box, placed between the os hyoides and the trachea, and communicating below with the air-tubes of the lungs, and above with the mouth and the nasal passages. It is composed of five cartilages, viz. the *thyroid*, the *cricoid*, the two *arytenoid*, and the *epiglottis*, which are movable upon one another by the action of several muscles. The whole larynx may also be elevated towards the chin, or depressed towards the sternum, by the action of numerous muscles.

The principal part of the larynx is the superior. At its upper and back part are two small pyramidal bodies, called the arytenoid cartilages. These have a sliding motion in every direction upon the cricoid cartilage, to which they are attached by a strong ligament. On the inside of the larynx there are two ligaments, formed of elastic and parallel fibres, and extending forward from the anterior part of either arytenoid cartilage to the thyroid cartilage, where they meet. These are called the *chordæ vocales*, or the vocal ligaments. The opening between them is the entrance into the windpipe, and is called the *glottis* or the *rima glottidis*. This narrow chink is capable of being enlarged, contracted, or wholly closed. Immediately above these two ligaments are two small pouches, termed the ventricles of the larynx, and above the ventricles are situated two other ligaments formed of mucous membrane, and extending between the arytenoid and thyroid cartilages, above the *chordæ vocales*. So that the ventricles of the larynx are situated between these ligaments and the vocal chords.

All the modifications of the voice are produced by the air passing out of the lungs through the larynx. The sound is occasioned by the vibrations of the vocal ligaments. According to Magendie, the gravity or acuteness of the sound depends on the greater or less approximation of the arytenoid cartilages towards each other. But Mayo remarks, that the pitch of the voice has no reference to the size of the aperture between the vocal chords, nor to any alteration of their length, but depends solely on their *tension*, and consequently, on the frequency of their vibrations.

The larynx is raised by the action of several muscles, as the digastric, the genio-hyoid, the genio-glossal, the stylo-glossal, the stylo-hyoid, the stylo-pharyngeal, and the hyo-thyroid. During its elevation the glottis is contracted, and the vocal ligaments approximate nearer together, and the pitch of the voice is raised. On the contrary, the sterno-hyoid, sterno-thyroid, coraco-hyoid, and crico-thyroid, depress the larynx; and at the same time, the arytenoid cartilages are separated from each other, and the glottis is enlarged, and the voice becomes low, or grave.

The action of the arytenoid muscle, which extends from one arytenoid cartilage to the other, closes the glottis by drawing the two cartilages together, and bringing the vocal chords nearer to each other, while the crico-arytenoidei posteriores and laterales separate the arytenoid cartilages, and widen the aperture of the glottis. The thyro-arytenoid is considered as the most important of the muscles of the larynx, as it forms the lip of the glottis, and embraces the ventricle of the larynx, and is the principal muscle employed in the modulation of the voice. Its office is to draw the arytenoid cartilages outwards and forwards, enlarge the

glottis, and shorten and relax the vocal chords. It also compresses the ventricles of the larynx.

The theory of the formation of the voice, according to Magendie, is as follows. The air forced from the lungs, at first passes into a tube of considerable size; but this tube soon becomes contracted, and the air is obliged to pass through a narrow slit, the sides of which are formed of vibrating plates, which alternately give passage to, and intercept the air, like the reeds of wind instruments; and by these alternations, produce the sonorous undulations in the current of air, transmitted through the aperture.

The inferior ligaments of the glottis owe their faculty of vibrating, to the contraction of the thyro-arytenoid muscles; and consequently, without the contraction of these muscles, no voice can be produced. Hence, a paralysis of these muscles occasions a loss of the voice; and for the same reason, a division of the recurrent nerves, which are distributed to the thyro-arytenoid muscles, destroys the voice.

The superior laryngeal nerves are distributed to the muscles which close the glottis, and the inferior to those which dilate it. Hence the division of the latter, or the recurrent, not only occasions a loss of voice, but sometimes produces asphyxia, because the constrictor muscles of the glottis, having no longer any antagonists to their action, contract without opposition, producing a closure of the glottis and suffocation. An aneurism of the arch of the aorta sometimes leads to the same consequences. The left recurrent nerve, which turns round the arch of the aorta, is stretched by the aneurismal tumour, and its functions impaired or destroyed; the voice is altered or lost, and suffocation sometimes takes place, even without the rupture of the aneurism.

According to Magendie, an opening in the trachea, below the larynx, destroys the voice, both in man and in other animals; if the aperture be mechanically closed, the voice is restored. Magendie mentions a man who had a fistulous opening in the larynx, and who was unable to speak, unless he wore a tight cravat, which covered the opening. An opening in the larynx below the inferior ligaments of the glottis, also occasions a loss of voice. On the other hand, a wound above the glottis, even if it injures the epiglottis and its muscles, or an injury of the superior ligaments of the glottis, and even of the superior part of the arytenoid cartilages, does not destroy the voice. Tubercular cavities in the lungs sometimes occasion a loss of voice.

The loudness or intensity of the voice depends on the extent of the vibrations of the vocal chords. This will depend on the quantity of air expelled from the lungs, and the force with which it is driven through the larynx, and upon the length of the vocal chords, or the size of the larynx. A vigorous person, with a

capacious chest, and a larynx of large dimensions, has all the conditions favourable to a strong voice. While children, women, and eunuchs, in whom the larynx is comparatively small, have in general much feebler voices than a healthy man.

Magendie found, upon laying bare the glottis of a dog by an incision between the thyroid cartilage and the os hyoides, that when he uttered grave sounds, the ligaments of the glottis vibrated throughout their whole length, and that the air expired passed out through the whole extent of the slit formed by the lips of the glottis, except at the interval between the arytenoid cartilages, which he says are always, during phonation, exactly applied to each other, and suffer no air to pass between them. When the animal uttered acute sounds, on the contrary, the ligaments vibrated, not in their anterior, but only in their posterior part, and the air passed out only through the corresponding portion of the glottis, and consequently through a smaller opening than in the former case. When the sounds became very acute, the ligaments vibrated only at the extremities nearest the arytenoid cartilages, and the air passed out only at this part of the glottis, which did not exceed two lines in length.

As the principal office of the arytenoid muscle is to close the glottis at its posterior extremity, it must be the principal agent in the production of acute sounds; and accordingly, Magendie found that the section of the two laryngeal nerves, which supply this muscle, destroyed the power of making acute sounds, and the voice of the animal acquired an unusual gravity. The thyro-arytenoid muscles, Magendie thinks, must exert some influence upon the tones of the voice. The more forcibly these muscles contract, the more their elasticity must be increased, and the more capable they must become of vibrating rapidly, and of producing acute sounds. The less forcibly they contract, on the contrary, the less rapidly they will vibrate, and the graver will be the tones which they produce. The contraction of these muscles, also, probably contributes to close the anterior part of the glottis.

The ventricles of the larynx, immediately above the inferior ligaments, are supposed by Magendie to be designed to isolate these ligaments, so as to allow them to vibrate freely in the air. If foreign substances be introduced into them, or they become filled with mucus or a false membrane, the voice generally becomes enfeebled or totally lost.

The glottis is connected by a remarkable synergy with the abdominal muscles. By the action of these muscles a certain degree of pressure is exercised upon the viscera of the abdomen, by which these organs are forced up against the diaphragm, and the glottis remaining open, the air of expiration is expelled from the lungs—not that the aid of these muscles is necessary in ordi-

nary or unexcited respiration, but in making forced or rapid expirations, their assistance is indispensable. It appears then, that when the glottis is open, the abdominal muscles can produce no other effect than to depress the ribs, compress the lungs, and force out a part of the air contained in these organs. But we know that these muscles are subservient to other functions, especially bending the trunk, and executing other motions of the body; and to the expulsion of the contents of the stomach, intestines, uterus, and bladder, in the acts of vomiting, defecation, parturition, and the evacuation of the urine. Whenever, therefore, the action of the abdominal muscles is required for any of these purposes, and in general, for any object other than the expulsion of air from the lungs, it becomes necessary that the glottis should be accurately closed; and this is effected, according to Bourdon, not by means of the epiglottis, but by the approximation of the vocal chords and of the arytenoid cartilages. Bourdon found, on laying bare the glottis in a dog to which he had a few minutes before given an emetic, that the moment the abdominal muscles began to act with force, the glottis became accurately closed, and that the epiglottis had no part in the effect. That the closure of the glottis is necessary, in order to suspend respiration and retain the air in the lungs, in making expulsive or other efforts requiring the action of the abdominal muscles, Bourdon ascertained by introducing into his own larynx a small canula of gum elastic, when he found that it was impossible to utter his voice, to cough, or to make any expulsive effort. The moment the abdominal muscles began to contract, the air escaped from his lungs, and the whole action of these muscles, and of the extensors of the trunk, was expended in producing expiration. He then closed the canula, after taking a deep inspiration, and found that he could suspend his respiration, move the trunk of the body, in a word, make all the usual efforts requiring the action of these muscles.

By making an opening into the trachea in dogs, and introducing a canula into it, he found that these animals were deprived of the power of swimming or leaping. An excellent swimmer on which this operation was performed, and which was afterwards thrown into the water, immediately sunk to the bottom; and another dog, prepared in the same manner, in attempting to leap a narrow ditch filled with water, fell into the middle of it. In both cases the muscular effort became successful afterwards, in consequence of stopping the orifice of the canula. In another dog, an emetic administered directly after opening the trachea was followed by nausea, and repeated but ineffectual efforts to vomit. All endeavours to retain his breath were in vain. Inspiration was constantly and rapidly succeeded by the escape of the air from the trachea. In the end, however, the efforts to

vomit were followed by the complete but gradual evacuation of the contents of the stomach, by the unassisted action of this organ itself; a fact from which Bourdon inferred, that the abdominal muscles are powerful auxiliaries in the act of vomiting, especially that kind which takes place suddenly; but that the stomach, without any assistance from these muscles, is capable of evacuating itself completely. From these experiments it appears that a free opening in the trachea converts the abdominal muscles wholly into muscles of expiration.

CHAPTER XXIX.

GENERATION.

This is a function by means of which organized living beings reproduce their like, and are thus enabled to perpetuate their species. The modes of generation are very various, though there is a general analogy running through the different modifications of the function, existing in the different forms of organized life.

In all the superior classes of animals a peculiar set of organs exists, to which this important function is assigned. In the lowest orders of animals, as the *infusoria*, the *polypus*, the *hydatids*, and some of the *intestinal worms*, no such organs exist.

In the first case, where organs of generation exist, these, in some animals are not divided into male and female, and of course there is no distinction of sex. Every individual is provided with the organs in question, and no copulation is necessary.

In other animals the organs are of two kinds, male and female, and of course a distinction of sex exists; and a union of two individuals is necessary to generation. But here there is a distinction; for in some cases each individual is provided with both kinds of organs, male and female, so that a double copulation is effected by a union of two individuals, both of which become impregnated; and in some others, the two sexes exist separately in different individuals, so that some are male and others female; and the union of two individuals of different sexes, by which only the female is impregnated, is necessary to generation.

In some species of animals of the latter kind, one impregnation is sufficient to make several generations fruitful. This is the fact with the *aphides*. In some others a single impregnation enables the female to produce young for several times. This is the case with many of the amphibia, and with birds.

Lastly; in the highest class of animals, the mammalia, one impregnation suffices for one birth only.

Organs.

The organs of generation in man and the higher animals are very complicated, and are divided into male and female.

In the male the essential part of the apparatus is the testes and in the female, the ovaries. The testes are glandular bodies, which secrete a prolific fluid, which is necessary to the impregnation of the female. The ovaries are also glandular substances, containing small vesicles, which differ in number in different animals, and in the human species amount in every female to sixteen or twenty. These vesicles are considered as the ova, or eggs of the female, containing the rudiments of the future being, but requiring for their developement the prolific influence of the male fluid.

Male organs. In adult males of the human species, and many of the mammalia, the testes lie in a sac called the scrotum; in some others they always lie concealed in the cavity of the abdomen, as in the *cetacea;* and in some of the mammiferous animals, as hares and rabbits, they change their situation, so that during copulation they are lodged in the scrotum, but at all other times in the abdominal cavity.

The testicles are two glandular organs, of an ovoid figure, a little flattened or compressed, and consisting of blood-vessels and innumerable convoluted, seminiferous ducts, disposed in lobules, which are separated by delicate cellular septa. The seminiferous vessels are so fine, that neither quicksilver nor any other injection can be forced from the spermatic artery into these canals, nor backwards from the excretory ducts of the testes, into the spermatic arteries or veins.* Each lobule contains one of these canals. The number of them is very great, amounting, it is said, to about three hundred, each of which is about sixteen feet long, and the length of the whole, near five thousand feet. Towards the superior part of the testicle, they unite into several larger canals, called the *vasa efferentia*, which anastomose with one another, and uniting into ten or twelve principal trunks, pierce the *tunica albuginea*, form numerous convolutions, and terminate in the head of the epididymis. This is a sort of appendix of each testis, situated on its upper and posterior part. It is composed of a single convoluted tube, about thirty feet long, the convolutions of which are connected together by cellular tissue. This

* Vide Berthold. Soëmmering, however, according to Blumenbach, was so successful as to inject all the vessels composing the testes and the head of the epididymis, with mercury.

canal at the inferior extremity of the epididymis, becomes larger and less convoluted, and turns and ascends behind the testicle into the abdomen, forming part of the spermatic cord, under the name of the *vas deferens.* After entering the abdomen, it separates from the other parts of the spermatic cord, descends into the pelvis by the side of the bladder, to which it adheres, and converging towards the duct of the opposite side, communicates with the vesicula seminalis, and at length opens into the urethra, near the neck of the bladder.

The vesiculæ seminales are two convoluted tubes, situated one on each side, near the neck of the bladder, between the bladder and rectum. They communicate freely with the vasa deferentia, and are considered as continuations of these tubes. The vesiculæ seminales are sometimes absent. The testicle is invested with a fibrous membrane, of a whitish colour, termed the tunica albuginea, very firm and resisting, yet susceptible of great distention, as certain enlargements and engorgements of this gland sufficiently prove. This coat is designed to protect the organ from external injuries, and to give it the necessary firmness. Its external surface is covered by the posterior part of the external face of the *tunica vaginalis,* to which it adheres very intimately. This tunic is a process of the peritoneum, and is a serous membrane, investing the testicle, and lining the scrotum.

The testicle is suspended from the abdominal ring by a bundle of vessels and nerves, called the spermatic cord, formed of the blood-vessels and nerves, &c. which pass to and from the testicle, as the spermatic artery and veins, lymphatics, nerves, and the vas deferens, connected together by cellular tissue. It is covered externally by a fibrous coat.

The bag in which the testicles are contained, is called the scrotum. It is formed by a continuation of the skin of the inner side of the thighs, and of the perineum. It is composed of two symmetrical halves, separated by a raphe. The skin which forms this sac is corrugated and contractile. Beneath the outer skin are two reddish vascular membranes, which form two distinct sacs, one for each testicle; and a septum, or partition, between them. This tunic, which is termed the *dartos,* is generally considered to be cellular in its texture, though some anatomists have regarded it as muscular. It possesses a strong contractile power. Beneath it is a third tunic, which is evidently muscular, and is called the *cremaster muscle.* It arises from the lesser oblique muscle of the abdomen, passes through the abdominal ring, contributes to the formation of the spermatic cord, and is lost on the inner surface of the scrotum. It draws the testicles upwards.

The *prostate gland* is an organ of a very compact texture, lying between the vesiculæ seminales, and embracing the neck of the bladder. It is considered as a congeries of glandular

follicles, which are filled by a viscid, whitish fluid. These follicles have numerous excretory ducts, which open into the urethra.

The male organ of generation, or the *penis*, consists of the urethra, surrounded by a spongy body, and of two other spongy substances, which last constitute much the larger part of the organ. It is a cylindrical body, composed of a vascular and erectile tissue, is provided with several muscles, and is situated at the inferior and anterior part of the abdomen, below and before the *symphysis pubis*.

The canal of the urethra, which runs the whole length of the penis, is situated along its inferior part. It commences at the mouth of the bladder, receives in its course the ejaculatory ducts and the excretory canals of the prostate gland. The glands of Cowper, also, open into it, besides mucous follicles. According to Amusat, the urethra is nearly straight when the rectum is empty, and the penis directed forwards and upwards. But when the organ is flaccid, the direction of the urethra is flexuous, having several curvatures.

The urethra is lined with a mucous membrane. That portion of the urethra which forms part of the penis, is supported by a spongy substance, called the *corpus spongiosum*. This is of a cellular structure, inclosed by condensed cellular membrane. The cells when injected, appear to be composed of a network of arteries and veins. Anteriorly, the urethra swells out into the glans penis, a roundish body, forming the extremity of the organ, and perforated by the orifice of the urethra.

The two other substances which contribute to form the penis, and which constitute about two-thirds of its volume, are the *corpora cavernosa*. These bodies are cellular like the corpus spongiosum, but the cells are larger, and consist almost wholly of dilated veins. The corpora cavernosa, together with the corpus spongiosum, are surrounded by common integuments, which adhere to them very loosely by cellular substance. At the neck of the glans, they become loose and pendulous, forming for the gland a covering called the prepuce. The corpora cavernosa and the corpus spongiosum, with the glans penis, belong to the erectile tissues.

The testicles derive their blood from the spermatic arteries, which generally spring directly from the abdominal aorta, and are remarkable for their great length. Upon reaching the testicles, each of them divides into two branches, one destined to the epididymis, the other to the testicle. The spermatic veins arise in the interior of the testicles, by very fine radicles. These veins accompany the ramifications of the arteries, emerge from the testicle by piercing the tunica albuginea, and then unite with the veins of the epididymis. They then ascend along the spermatic cord, anterior to the vas deferens, running in a tor-

tuous direction, and entering the cavity of the abdomen where those of the right side open into the vena cava, and those on the left into the corresponding renal vein. The spermatic veins, of which there are two or three on each side, are furnished with numerous valves.

The nerves of the testicles are furnished by the great sympathetic.

The penis derives its blood from a branch of the internal pudic artery, which originates in the internal iliac. The veins follow the same course as the arteries. The organ is supplied with nerves by the internal pudic, which derives its origin from the second and third sacral nerves, forming junctions with the great sacro-ischiatic, the trunk of the intercostal, and the splanchnic nerves.

The use of the testes is to secrete a prolific fluid, termed the semen, or male sperm, which is necessary to the impregnation of the female. The principal use of the penis is to project this fluid into the organs of the female.

The semen is a whitish, semi-transparent, albuminous fluid, containing in a large proportion of water, animal mucus, a peculiar animal matter, sulphur, soda, and phosphate of lime. It has a peculiar characteristic odour, said to bear a strong resemblance to that of the pollen of many plants.

When the semen of a man, or of an adult animal, is viewed through a microscope, an immense number of animalcula, resembling tadpoles in their shape, are seen in it, swimming about with great vivacity. They are observed in the human fluid only after the time of puberty. They disappear, as it is alleged, during many severe sicknesses, and do not exist in the semen of old men. In dogs they are present only during the season of their amours; and in hybrids, as the mule, which are incapable of propagation, they do not exist at all. It is remarkable that these animalcula differ in different species of animals, but are always alike in the same. Their number is so prodigious, that in a little drop of the spermatic fluid of a cock, hardly exceeding a grain of sand in size, they are said to amount to fifty thousand. By some physiologists they have been considered as the direct agents of impregnation.

The course of the semen after its secretion from the blood of the spermatic artery in the testicles, is through the tubuli seminiferi to the epididymis, the vas deferens, and the vesiculæ seminales, where it is supposed to be deposited until it is needed during the venereal act. It then passes into the urethra, and is projected by the male organ in jets.

The use of the vesiculæ seminales is not known, though by some they are supposed to be reservoirs of the semen, as the gall-

bladder is of the bile. Whatever may be their use, they are not essential to generation, as many animals are not provided with them.

Female organs. The sexual organs in females consist of the *ovaries* and their appendages, with the uterus, and the parts more immediately belonging to it. Or they may be divided into *organs of secretion*, and *organs of reception;* the first embracing the ovaries and the Fallopian tubes; the second, the uterus, the vagina, and the vulva.

The *ovaria*, which are the essential parts of the female sexual apparatus, are two oval-shaped glandular bodies, about an inch and a half long, and about half an inch in diameter, situated in the abdomen, enveloped by the posterior fold of the broad ligament of the uterus, and each being retained in its place by its proper ligament, called the ligamentum ovarii. They are invested with a peritoneal coat continuous with the posterior lamina of the broad ligament of the uterus. The ovaries are composed of a dense cellular substance, containing a number of small vesicles, filled with a limpid albuminous fluid. These vesicles, which are fifteen or twenty in number, are of various sizes; the larger lying near the surface, the smaller more towards the central parts of the ovaria. The largest of them are about three lines in diameter. They are considered as the unimpregnated eggs of the female, and each is supposed to contain the rudiments of a fœtus. The size of these ova is by no means in proportion to that of the animal to which they belong. In the elephant, for example, they are very small. The fluid contained in them is analogous to the white of an egg, being coagulable by heat and by alcohol.

The ovaria are connected to the uterus by the broad ligament of the uterus, by the proper ligaments of the ovaria, and by the Fallopian tubes.

The Fallopian tubes are narrow, tortuous canals, which arise from the angles of the fundus uteri, and run in the upper part of the duplicature of the broad ligaments. Their length is from three to five inches. The extremity which opens into the uterus is extremely small, being scarcely large enough to admit a hog's bristle. But the tube gradually enlarges towards the ovarian extremity, where it is about four lines in diameter. The Fallopian tubes are composed each of a layer of longitudinal muscular fibres,* and, within this, of another layer of circular ones, lined with a mucous coat, which extends from the corner of the fundus uteri to the ovarian extremity of the tube, where it contributes to form what is called the *corpus fimbriatum.* The ovarian aperture is sur-

* Some physiologists deny the muscularity of the Fallopian tubes.

rounded by an elegant fringe, derived from the peritoneal covering of the tube and of its mucous membrane, and it opens into the cavity of the abdomen.

The Fallopian tubes are attached by one of their fimbriæ to the ovaria.

The *uterus* is a hollow organ, situated between the bladder and rectum, and designed for the reception and evolution of the fœtus. It is of a pyramidal figure, about two inches long, flattened on its anterior and posterior surfaces, and is divided into a fundus, a body, and a neck. The fundus is the upper part of the organ; the neck or cervix, the inferior part, which opens into the vagina; and the intermediate part constitutes the body. The walls of the uterus are very thick, particularly in the body of the organ, where they are nearly half an inch in thickness. The substance of which the uterus consists is peculiar in its organization, and its real characters are not well ascertained. It is a dense, compact tissue, abounding in blood-vessels, lymphatics, and nerves, and, according to some physiologists, is decidedly muscular. Some anatomists consider the fibres of the uterus as analogous to the yellow fibrous tissue which exists at the common limits of the cellular and muscular system, approaching the first in the unimpregnated uterus; but assuming all the characters of the second in the latter stages of utero-gestation. Others regard the tissue of the uterus as condensed cellular tissue. Blumenbach says, that he never yet discovered a true muscular fibre in any human uterus which he had dissected.

Externally the uterus is covered with a peritoneal coat. The peritoneum is reflected over the anterior and posterior surfaces and the fundus of the organ; and these two laminæ of the membrane, uniting together at the sides of the uterus, form a broad ligament, which invests the Fallopian tubes and ovaria; and which divides the cavity of the pelvis into two parts. The uterus is also connected with the neighbouring parts by other ligaments, as the anterior and posterior, and the round ligaments. Internally, the cavity of the uterus is lined by a mucous membrane. This cavity, which is about large enough to contain an almond, is triangular in its shape, and has three apertures, viz. two at the fundus, which are the orifices of the Fallopian tubes, and the third at the inferior angle, communicating with the vagina, and called the mouth of the uterus, and sometimes the *os tincæ*.

Between the mouth of the uterus and the external opening of the organs of generation, is a canal from four to six inches long, and one or one and a half inches in diameter, termed the *vagina*. It consists of a very vascular cellular tissue, lined with a mucous membrane, presenting numerous semicircular rugæ. It is somewhat curved in its direction, with its concavity towards the bladder, and its upper part receives the neck of the uterus.

The orifice of the vagina is surrounded by a sphincter, called the *constrictor vaginæ.*

Near the external orifice of the vagina is a circular membrane, called the *hymen*, formed by a duplicature of the mucous membrane of the vagina, with an aperture in its centre. It is found only in the human subject, and, for the most part, only in the virgin state. The vagina opens externally by the vulva. This is formed by the *labia pudendi,* two oblong bodies, composed of a duplicature of the common integuments, with adipose matter interposed. They extend from the symphysis pubis to the perineum, meeting at their superior and inferior extremities by commissures, but in their intermediate parts being separated by a narrow orifice, which is the opening of the vagina.

At the upper commissure of the labia is a small organ, called the *clitoris,* which has some resemblance to the male penis, consisting of corpora cavernosa, capped with a glans, which, however, has no perforation, as the organ is destitute of a urethra. From the clitoris, and within the labia, descend on each side of the vagina, the *nymphæ* or internal labia. They reach down to the inferior commissure, where they are blended together. The nymphæ are prolongations of the mucous membrane of the vagina, and consist of a delicate spongy tissue, which is continuous with that of the glans clitoridis. About an inch from the glans of the clitoris, within the vagina, under the arch of the pubes, is the orifice of the urethra.

The ovaria receive their blood from the spermatic arteries, and their nerves from the renal plexus. The uterus is supplied with blood by means of the uterine arteries, which are branches of the internal iliac, and its nerves from the renal and hypogastric plexuses.

Menstruation. At the approach of puberty, and apparently to prepare the uterus for the important function it is soon destined to perform, a discharge of a bloody fluid from this organ appears for the first time, and continues to recur at periods of a lunar month, until the age of child-bearing is past. The age at which this evacuation first takes place varies in different climates and under different circumstances. In temperate climates, it usually begins between the ages of thirteen and fifteen. The time of its duration is about thirty years, and it ceases at the age of forty-five or somewhat later.

The quantity of fluid discharged at each menstrual period is from six to eight ounces; and the length of each period is usually three or four days. Though the fluid discharged appears to be blood, it differs from it in some respects, particularly in not being coagulable, and is regarded as the product not of a hemorrhage but a secretion. In certain cases it has been retained for many months in the uterus, and eventually discharged in a fluid state.

The first appearance of the menstrual evacuation is generally preceded by pain in the loins and pelvis, disorder of the stomach and bowels, as sickness, inflation, colic pains, restlessness, nervous irritability, hysterical symptoms, frequent pulse, &c. These symptoms usually abate when the discharge takes place, but a feeling of debility frequently remains.

This secretion is generally suspended during pregnancy, and for some time after parturition. Yet instances now and then occur, in which menstruation takes place in the usual manner during the period of utero-gestation; though it is asserted that in these cases the fluid discharged is coagulable, and consequently pure blood.

Menstruation usually coincides with the age of puberty, and its first appearance is accompanied by other changes which announce the arrival of this important epoch in the female system. Thus the breasts and pelvis enlarge, and the uterine organs are developed, and a visible change takes place in the temper and tastes of the female.

A similar discharge has sometimes been observed in young children, but this should not be confounded with menstruation, unless accompanied with other signs of precocious puberty. I was recently informed by an intelligent lady, that a daughter of hers, who is now five years old, had a bloody discharge from the vagina, when only nine months old. It continued a day and a half, then disappeared, and returned after an interval of five weeks. It then ceased permanently, but was succeeded by a leucorrhœal weakness, which lasted a considerable time.

Impregnation. Impregnation is effected by the influence of the male fluid upon the ova of the female; and the functions of a very considerable part of the sexual apparatus in both sexes, are subservient to the object of effecting the approximation of these two essential elements of generation. To the accomplishment of this object, the intromission of the male organ into the female vagina, and an ejaculation of the prolific fluid into the interior of the sexual organs of the female, are necessary.

To adapt it to this function, the penis, which is composed of an erectile tissue, has the power, when under the influence of sexual desire, of becoming rigid and swollen from a congestion of blood in its corpora cavernosa, the urethra, and glans. Artificial erection may be produced after death, by injecting the organ. The congestion is evidently of an active kind, as appears from the increased throbbing of the arteries of the part. The blood is solicited into the organ by the peculiar irritation which affects it at the time, and is accumulated in the venous plexuses of which the erectile tissue of the organ consists. Cuvier was of opinion, that the veins are chiefly concerned in the production of erection, because they predominate so much in the structure

of the corpora cavernosa, and because the nerves, which are the conductors of the mental stimulus, terminate chiefly in the veins. Perhaps both the arteries and the venous plexuses are concerned in the effect.

The erection of the penis bestows on the organ the necessary degree of firmness to effect the penetration of the external organs of the female. But the ejection of the male fluid, during the introduction of the penis, is also necessary. The irritation which gives rise to the erection of the penis, continues during the venereal act, and extends to the rest of the genital apparatus. Under the influence of it, the testes secrete the male fluid more copiously, which passes through the excretory canals of the two glands, into the vesiculæ seminales. These reservoirs partake in the excitation, contract forcibly, and project the spermatic fluid into the urethra, which canal becomes excited to the highest degree of orgasm by the contact of the fluid. The excitement extends to the ischio and bulbo-cavernosus muscles, the transversus perinei, and the levator ani. The first of these muscles keeps the organ erect, and in a proper direction for its introduction into the vagina; and they all concur in projecting the fluid along the urethra. By the agency of these powers the semen is ejected from the urethra, in jets, into the vagina of the female. With the seminal liquor are ejaculated the fluids secreted by the prostate gland and the glands of Cowper.

According to some physiologists, the seminal fluid is accumulated in the bulb of the urethra previous to its emission. The bulbous part of the urethra seems to be well fitted for the purpose, and the muscular contraction, by which the emission of the fluid is effected, first acts upon this portion of the canal.

During the venereal act, the female, as well as the male organs are in a state of erection. The clitoris, and the erectile tissue, which lines the interior of the vulva and the vagina, are in a state of turgescence, and a considerable secretion of mucus takes place from the surface of the vagina.

The completion of the act is succeeded, on the part of the male, by a cessation of the local erethism, with a return of the penis to its ordinary state of flaccidity, and a feeling of languor and weakness. A similar state of feeling occurs in the female, though in a less degree.

It has been a disputed question with physiologists, to what point in the female organs the male fluid is projected, and where it exerts its fecundating power. Different opinions have been entertained on this question. According to some physiologists, the seminal fluid gets no farther than the superior part of the vagina; and they suppose, that fecundation is accomplished, either by the absorption of the semen by the vessels of the vagina, whence it reaches the ovaria in the course of the circu-

lation; or, by means of some subtle emanation, disengaged from it and conveyed to these organs. In proof of this opinion it is alleged that, on opening female animals immediately after copulation, no semen can be discovered in the uterus. The extreme narrowness of the Fallopian tubes furnishes another argument in favour of this opinion.

Others suppose that the spermatic fluid is projected into the uterus, but no farther; that the female organs furnish another material, which also is conveyed into the uterus, and that impregnation results from the mixture of the two.

According to a third opinion, a portion of the male fluid is conveyed by a peculiar action of the Fallopian tubes, to the ovaria, where fecundation is accomplished.

The last opinion is regarded as most probable, at least with respect to the human species. No doubt can exist that fecundation takes place in the ovaria, and that the influence of the male fluid must, in some mode or other, be conveyed thither. The developement of the fœtus in the Fallopian tubes, in the ovaries themselves, and even in the abdomen, probably from an escape of the impregnated ovum out of the ovarian extremity of the Fallopian tubes, furnish strong evidence of the truth of this opinion. Nuck once effected a pregnancy of the Fallopian tube in a bitch by applying a ligature, three days after copulation, to one of the horns of the uterus. It is true, that in some animals, as fishes, the ova are not fecundated until they have been evacuated from the body, and of course, in these animals at least, impregnation certainly does not take place in the ovaria.

It appears to be ascertained that the seminal fluid does in fact reach the uterus. Some physiologists, it is true, could never discover it in this organ after copulation. But others have been more successful. Thus Haller found it in a sheep; Ruysch, in the uterus of a female who was caught in the act of adultery by her husband; and MM. Dumas and Prevost, even in the Fallopian tube. These last mentioned physiologists admit that they have seen it even in the Fallopian tubes. It appears to be necessary that there should be actual contact of the spermatic fluid with the ova to effect impregnation. Thus, in an experiment of Spallanzani, ten or twelve grains of semen were put into a watch-glass, and twenty ova into another, which was placed over the former, but in such a manner, that no contact took place between their contents. After some hours, the seminal fluid was evaporated to such a degree, that the ova were moistened by the vapour, but still they were not fecundated by it. But fecundation was produced by the residue of the semen, as soon as the ova were placed in contact.

Dumas and Prevost made an experiment of a still more conclusive kind. They prepared fifty grains of a prolific liquor,

with the fluid expressed from twelve testicles, and as many vesiculæ seminales. With ten grains of this they fecundated more than two hundred eggs. The remaining forty grains were then put into a small retort, with an adopter fitted to it. In the adopter were placed forty eggs. The apparatus was then placed under a pneumatic receiver, and the air exhausted, until one half of the atmospheric pressure was removed. The retort was afterwards exposed to the rays of the sun, in order to raise its temperature. After four hours, some of the eggs were found bathed in a clear liquid, which was the product of the distillation, and swollen, but without presenting any appearance of developement. Those of the eggs which were placed near the back of the retort, had undergone no change. Impregnation, however, was afterwards effected by plunging the eggs in the liquor which remained. It appears, therefore, that the volatile part of the spermatic fluid, which is raised by distillation, has no prolific power; while the fixed part, which remains, retains this power unimpaired.

It must therefore be concluded, that actual contact between the seminal liquor and the ova is necessary to impregnation, and that the former must be conveyed from the uterus to the ovaria by the Fallopian tubes.

It is probable that, during the orgasm of copulation, the Fallopian tubes partake in the erection which affects the sexual organs, and apply their pavilion, or ovarian extremity, to the ovaria, and convey thither a portion of the spermatic fluid. The extreme narrowness of the Fallopian tubes at their uterine extremity, affords no solid objection to this opinion; for we know that at a later period, these canals admit of the passage of the impregnated ovum into the uterus; and besides, it must be considered that an exceedingly minute portion of the seminal fluid is sufficient for impregnation. It is also known, that in plants, the pollen of the stamina must traverse the vessels of the style, in order to produce fructification; and these canals are undoubtedly much narrower than the Fallopian tubes in animals.

From numerous observations, made by different physiologists, it appears that the spermatic fluid, after passing from the uterus through the Fallopian tubes, comes into contact with one or more of the vesicles of the ovaria; that the vesicles which have been exposed to this contact at first swell, and afterwards burst their envelope, and permit the escape of a minute body, which has generally been considered as an ovum, which is conveyed into the uterus by the Fallopian tube, and becomes the rudiments of the future fœtus. The *debris*, or the pericarp of the ovule, remains in the ovaria, under the name of the *corpus luteum*. It appears from these facts that the Fallopian tubes execute a double office, viz. that of conveying the seminal fluid from the uterus to

the ovaria, and afterwards that of bringing an impregnated ovum from the ovaria to the uterus. In proof of these facts, it appears that during the spasm of copulation, the pavilion of the Fallopian tube always closely embraces the ovaria. De Graaf, in his experiments, found it thus adhering twenty-seven hours after copulation. This close grasping of the ovaria, by the pavilion of the Fallopian tube, is very intelligible, if we suppose its object to be to convey something to and from the ovaria. Magendie, in one instance, actually saw the extremity of the Fallopian tube applied to a single vesicle. Abdominal and tubular pregnancy are an evidence to the same effect. If the pavilion suffers the ovum it has embraced to escape, the latter falls into the abdomen, and abdominal pregnancy is the consequence. If by any cause the ovum is arrested in its passage through the tube, tubular pregnancy is the result.

Haighton found, that when he divided the Fallopian tube on one side, in rabbits, impregnation took place only on the uninjured side. When he made this section after copulation, he found that it prevented the passage of the ova into the uterus, if the operation was performed forty-eight hours after the sexual act; but if delayed for sixty hours it failed of producing this effect. A surgeon, named Bussieres, once had the rare opportunity of seeing an ovum partly adherent to the ovary, and partly detached and engaged in the Fallopian tube.

It is very doubtful what kind of action these tubes exert in conveying the ovum to the uterus. Some physiologists contend that they are muscular, and contract like other muscular canals; but it is more probable that they exert an erectile action, the consequence of the spasm into which the organs of generation are thrown during the venereal act.

It is a well-known fact, that hen birds which have not been impregnated by the male, sometimes lay eggs, which, however, are unfruitful; and a similar fact seems to be ascertained with respect to viviparous animals. Buffon asserted the existence of *corpora lutea* previous to impregnation; and Cruikshanks says, that he had seen them in the ovaries of virgin rabbits. Sir E. Home declares, that he had seen corpora lutea in the ovaria of women who had died virgins; and he asserts that, in the females of quadrupeds, in heat, and in women at indeterminate periods, the ovaries suddenly become vascular, and ova escape from them and pass through the Fallopian tubes, which are then in a state of turgescence, or erection, with their pavilion closely embracing the ovaries, to the uterus. These phenomena recur whenever the animal is in heat, and in women at any time, until the critical period of life. It seems, therefore, that the females of viviparous animals, as well as birds, continually part with unfruitful

ova, and that fecundation depends on the concurrence of copulation with the presence of mature vesicles.

On the whole, it seems to be ascertained that corpora lutea may exist independently of sexual intercourse, merely from high venereal excitement; and under the same circumstances, it is probable that a vesicle sometimes bursts its envelope, leaving a corpus luteum behind, and escapes from the ovary, passes along the Fallopian tubes, which then closely embrace the ovaria, and enters the uterus; but being unimpregnated, undergoes no further developement, and may be discharged in the same manner as the unimpregnated eggs of oviparous animals.

It appears from the experiments of Brachet that impregnation is independent of cerebro-spinal innervation. He divided the spinal marrow, about the middle of the lumbar region, in a bitch while in heat, then dressed the wound, and having supported her in a standing position, permitted a dog to approach her. The wound, which was carefully dressed, healed in a week; but the animal lost her appetite, pined away, and died in about a month. Upon examination, the left horn of the uterus was found empty, but the right contained two well-developed embryos.

Brachet also relates the case of a lady, the mother of three children, who was seized with paraplegia, and in whom sensibility was completely abolished as high up as above the pubis, and no sensation accompanied the sexual act, yet under these circumstances she conceived and again became a mother.

Developement of the Fœtus.

It has not been ascertained how soon after a fruitful intercourse, the fecundated ovum descends into the uterus. Sir. E. Home fancied that he discovered in the uterus of a woman who died eight days after impregnation, an ovulum in which two opaque points were visible, which he supposed to be the rudiments of a fœtus. But Burns is of opinion, that at least three weeks elapse after conception, before the ovum enters the uterus; and he states, that in three instances he had carefully examined the uterus nearly a month after impregnation, and in neither had he been able to discover either ovum or fœtus.

At first the ovum contains no visible embryo; it consists merely of membranous involucra, containing a whitish semitransparent gelatine or mucus. Its envelopes are two in number, an external and an internal, the former denominated the chorion, the latter the amnion. Its exact size when it enters the uterus is not known; but Magendie states, that the smallest which have been examined were about the size of a pea, and their surface was every where covered with numerous filaments, which gave them a shaggy or villous appearance.

It is also undetermined how soon after conception, the rudiments of the embryo become visible through the membranes of the ovum. Burns states that he had carefully examined a perfect ovum the fifth week after conception, without being able to detect any embryo in it. The chorion was as large as a small chestnut, covered with shaggy vessels, and filled with a transparent jelly. Within and adhering to one side was the amnion, not much larger than a coriander seed, and containing nothing but a transparent fluid.

After a certain time, however, perhaps of about three weeks, several important parts become visible in the ovum, which are necessary to the developement of the fœtus. These are the amnion, which makes its appearance in the form of a small vesicle, adhering to the internal surface of the chorion; the first rudiments of the germ; a small spherical sac called the umbilical vesicle, and a little membranous pouch, termed the allantois, neither of them inclosing the germ, but situated between the chorion and amnion; the umbilical cord, which appears not long after, forming a communication between the germ and the internal surface of the chorion; the omphalo-mesenteric vessels, by which the umbilical vesicle communicates with the germ; and a prolongation of the allantois, designed to unite this membrane with the embryo. There are also certain fluids contained in the membranes above mentioned, viz. the liquid contained in the amnion, another between the amnion and chorion, and those of the umbilical vesicle and allantois.

Of these parts, which will be more particularly described hereafter, some are persistent, and continue during the whole of fœtal life; the others are deciduous, and disappear during the early months of pregnancy. The first are the chorion, amnion and its contained fluid, and the umbilical cord; the others are the umbilical vesicle and the allantois and their respective contents, the omphalo-mesenteric vessels, &c.

When the embryo first begins to be visible through the membranes, it forms a little oblong body, of from one to three lines in length, somewhat curved, and resembling a little worm. One of its extremities is of an oval or irregular spherical shape, the other tapers to an obtuse point. Some observers compare it to two oval bodies of unequal size united together. The larger of these is the head, the smaller, the trunk of the embryo. No rudiments of the limbs are yet visible; and the size of the ovum is equal to that of a filbert.

About the fifth or sixth week the embryo is five or six lines in length, and weighs about eighteen or twenty grains. The head is very large in proportion to the rest of the body, which is still curved, constituting about one half of the whole embryo. The face is now distinctly visible, but is very small compared with

the cranium. The rudiments of the eyes are also perceptible, being indicated by two black points situated at the sides of the face. No trace of a nose is yet to be seen, but a large transverse cleft occupies the place of the mouth. The rudiments of the external ear make their appearance at first under the form of a circular depression.

Towards the end of the second month the arms begin to sprout at the sides of the trunk; and a little later, the two inferior extremities appear like little roundish buds, at the inferior part of the body. The beating of the heart can now be perceived at the superior part of the abdomen; and at its inferior, which adheres to the ovum, the rudiments of the cord begin to be visible. In the seventh week, the embryo is about the size of a bee, and in the eighth, it is twelve or fifteen lines in length, and weighs one or two drachms. The head now constitutes about one-third of the whole body. The eyes are proportionally larger than at a later period of fœtal life; and the iris is remarkable for its blackness. The rudiments of the nose now begin to appear, presenting two apertures in the situation of the future nostrils; and outside of the angles of the mouth two little orifices become visible, which are the rudimental openings of the auditory passages. About this time the circle of the iris is perceived to be closed by a white membrane. At the end of the eighth week, the eyes become somewhat prominent, and the nose a little salient; and the external ears present the appearance of semi-oval tubercles, with a longitudinal fissure. The rudiments of the eyelids begin to appear, and the nostrils are closed by a membrane of variable thickness.

About the beginning of the third month, the tubercles which indicate the future limbs become salient; and the fore-arm and hand may now be distinguished, though the arm is yet wanting; and the hand, which is longer than the fore-arm, is destitute of fingers. The upper limbs continue to be more developed than the lower. A little later, *i. e.* about the ninth or tenth week, the fingers become visible, and the toes appear under the form of small tubercles, connected by an intervening soft substance. The soles of the feet are turned inwards. The cord is now longer than the embryo, and begins to be twisted. Its base is funnel-shaped, and is directed towards the abdomen, with the cavity of which it communicates, containing a considerable part of the intestines. The place of its insertion is very low in the abdomen. The caudal prolongation of the spine gradually diminishes and finally disappears. The umbilical vesicle, also, generally disappears about this time. The volume of the ovum at this period is nearly equal to that of a pullet's egg. Towards the end of the third month the body of the fœtus, according to some physiologists, is from one to three inches long, but according to Chaus-

sier, as much as six. It is probably very variable in this respect, as physiologists differ widely in their accounts of its dimensions and weight. During this period the fœtus is rapidly developed, and the different changes succeed each other so quickly that it is difficult to determine the exact period when each of them takes place. At the end of the third month, the neck forms a visible separation between the head and thorax. The umbilical cord no longer contains any portion of the intestines, which are now wholly inclosed in the abdomen. The spiral turns of the cord are more numerous and distinct. The upper arm and thigh increase in length; and the nails begin to appear on the toes and fingers, in the form of thin membranous plates. The distinction of sexes becomes apparent in the conformation of the sexual organs. The orifice in which were confounded the openings of these organs, and the anus, is now divided by a membranous partition, and the two cavities thus isolated from each other. The arms of the fœtus are generally depressed upon the abdomen, while the legs are drawn up against the same part of the body.

At the fourth month, all parts of the fœtus are quite distinct; and about the middle of this month, Magendie remarks, the developement of all the principal organs is completed, and at this epoch of intra-uterine life, the embryo state of the new being terminates, and the fœtal commences. The head at this period constitutes less than one-third of the body, and the fontanelles are very large. The eyes, as well as the nostrils and mouth, are closed; the nose is depressed, the forehead wrinkled. The lachrymal points are visible, the external ear well formed, the chin begins to project, and the tongue may be seen in the posterior part of the mouth. The insertion of the cord is at a higher point of the abdomen, in consequence of the increased developement of the inferior parts. The lower limbs are much increased in length, so as no longer to be below their just proportion to the upper. The sex is now very apparent. The scrotum and raphe are quite manifest, the membrum virile long, and its glans uncovered. The clitoris also is of considerable length, and surmounts the labia, which are very apparent. The skin is of a rose colour, and covered with a light down, and on the head there is a short whitish hair. The length of the body is six or eight inches, and its weight about as many ounces.

At five months the length of the fœtus is from eight to ten inches, its weight about as many ounces. The head is now only one-fourth of the length of the whole fœtus; but its weight is much increased, and tends to keep it in the lowest position. The face differs but little in expression from that of a full-grown fœtus. The lower limbs now exceed the upper in length. The skin becomes covered with a whitish silken hair, especially towards the root of the nose. Muscular power is now considerably developed,

and the mother begins to feel very sensibly the motions of the child, possibly from the circumstance that the fœtus, from its increase in size, approaches nearer to the walls of the uterus. If born at this period, the child is capable of living a few minutes.

At six months, the length is twelve or fourteen inches, its weight nearly sixteen ounces. The head apparently is not so large in proportion to the body as before; yet its weight is still predominant, and it is covered with more hair. The eyes are still closed, and the eyelids as well as the eyebrows, are garnished with very fine delicate hairs. The pupillary membrane still exists. The skin is of a purple colour in the face, lips, ears, breast, palms of the hands, and soles of the feet. The dermis and epidermis are now distinguishable. The skin is wrinkled and in folds, in consequence of the small quantity of fat contained in the adipose cells. The scrotum is empty, very small, and of a bright red colour. The vulva is prominent, and its margins separated by the clitoris. A fœtus born at this period is viable for some hours.

At seven months it is fourteen or sixteen inches in length. Its head is towards the mouth of the uterus, but is movable, as may be felt by examination. The frontal, occipital, and parietal bones, present considerable prominences in their central part, at the spots where the first rudiments of ossification begin; and hence are less uniformly *vaulted* than at a later period.

Towards the end of this month, the eyelids partly open, and the pupillary membrane disappears. The fat is more abundantly secreted, and gives a fuller and more rounded form to the external parts. The surface becomes incrusted by a whitish sebaceous matter, either secreted by the cutaneous vessels, or deposited as some suppose by the amniotic fluid. The hair is longer and of a darker colour; and the testes begin to descend into the scrotum. A fœtus born at the end of the seventh month is viable, that is, may respire and live.

At the eighth month, the increase of the fœtus is chiefly in breadth. Its length is from sixteen to eighteen inches; its weight four or five pounds. The skin is very red and covered with a long down, the eyelids are open, and the scrotum contains one testicle, generally that of the left side. In the female, the labia are no longer separated by the prominence of the clitoris.

In the ninth month, the length of the fœtus is eighteen or twenty inches, its weight six or seven pounds. The insertion of the cord, which had been progressively rising higher and higher above the hypogastric region, by the developement of the parts below, now coincides nearly with the middle of the length of the fœtus. The down on the eyebrows and eyelids is replaced by hairs; and the hair of the head is an inch long or more. At the end of the ninth month, the child weighs from six to ten pounds, and sometimes even twelve.

During the whole of gestation, the position of the fœtus is such that the head is generally the most depending part. In the early periods of pregnancy this position may be owing to the place of insertion of the cord, which is in the lower part of the abdomen; and to the preponderance of the brain and liver over the pelvis and lower limbs, which are but little developed. In the later periods of uterine life, the position remains the same, because, although the cord becomes lengthened, and thus allows greater latitude of motion to the fœtus, yet, as the volume of the latter increases, and the space in which it floats is relatively diminishing, a change of position is not easily effected. The abdomen looks towards the fundus of the uterus, because the placenta is usually attached to the same part, and the breech is directed towards the anterior part of the abdomen. The body is bent forward, the chin resting upon the thorax; the occiput is directed towards the superior opening of the pelvis, the arms approximated towards each other in front, with the hands towards the face, the thighs bent upon the abdomen, which is directed upwards and backwards, the knees separated, and the legs crossed in such a manner that the left heel rests against the right buttock, and reciprocally. In this position the fœtus represents an ovoid mass about ten inches long.

At the end of nine months, the insertion of the cord corresponds exactly with the middle of the length of the body, a circumstance of some importance in enabling us to judge of the exact age of the fœtus.

The growth of the different parts of the body proceeds rapidly in the early stages of uterine life, but more slowly towards the end of gestation, apparently bearing some relation to the developement of the liver, which is very rapid at first, but ceases towards the close of the fourth month.

Developement of Internal Parts in the Fœtus.

According to Chaussier, the fertilized ovum is at first merely a little mass of semi-transparent mucus, or diffluent jelly. By degrees the various parts become differenced, and the rudiments of the organs begin to be sketched out in this apparently homogeneous mass; but the exact order in which some of the most important parts are developed is not fully determined.

Anatomists are divided on the question, whether the vascular or nervous system is developed first. According to Rolando, the nerves are the parts which first appear in the homogeneous mass; and Magendie remarks, that numerous observations have proved that the spine appears before all the other organs, and during a certain time exists alone. Observations on the incubated egg, on the contrary, have led other physiologists to the

opinion that the vessels, and especially the veins, are the parts which are first formed.

The brain and spinal marrow in the embryo exist at first in a fluid state. About the fourth week there is visible to the naked eye in this limpid fluid an opaque white or yellowish filament, which forms the rudiments of the cerebro-spinal axis. At this time the nerves of the trunk and head are also visible, and of course they cannot originate in the brain and spinal marrow. Between the fourth and fifth week, at the time when the umbilical cord is quite distinct, three vesicles may be observed in the head, but without any trace of a median line. The spinal cord is also single. At this period the nerves have formed no union with their centres, but are still isolated from the brain and spinal cord. About the thirty-sixth day, the cerebral vesicles are divided into two lateral halves, the three thus becoming six. The two anterior, which are the largest, correspond to the hemispheres of the brain; the two posterior constitute the origin of the medulla oblongata; and the two smallest, situated between the two other pairs, form the rudiments of the tubercula quadrigemina. The cerebellum is not yet visible.

The spinal cord is at first simple, but afterwards is composed of two lateral cords, which at a later period unite together. At the age of two months, the human embryo has the spinal cord open behind only at its superior part, a condition which is only temporary and of short duration; but in the batrachian reptiles continues during life. About the end of the seventh week the spinal marrow terminates in a point at the coccyx. All the mammalia, and man among them, have originally a coccygian tail; but those animals in which this appendage does not persist, lose it exactly at the same time, i. e. when the spinal cord rises in the canal, a process which, in the human embryo, begins in the second month of gestation. The marrow at first descends as far as the coccyx, but afterwards rises by degrees to the level of the first lumbar vertebra.

The nerves and the spinal marrow do not unite and become continuous until towards the end of the second month. The cervical nerves are the last to form this union.

The obliteration of the median canal of the spinal cord generally takes place in the course of the sixth month; and it results from the approach and increased size of the lateral cords. The spinal marrow has two enlargements, which coincide with the appearance of the upper and lower extremities.

The rudiments of the cerebellum make their first appearance in the course of the second month, in the form of two isolated plates, situated between the tubercula quadrigemina and the medulla oblongata. It has been observed that the cerebellum increases but little during the eighth month; while both in the

seventh and ninth its growth is considerable. It has been conjectured, that this circumstance may have some concern in the greater viability of the fœtus at the seventh than at the eighth month.

The tubercula quadrigemina in the mammalia are originally hollow, and divided by a median line, which is a continuation of that which separates the two lateral cords of the spinal marrow. In the mammalia this disposition is only temporary, but in the other classes of the vertebrata, the reptiles, fishes, and birds, it is persistent. In the human fœtus, this cavity of the tubercula quadrigemina disappears towards the sixth month.

The ventricles of the brain are at first proportionally larger than in adult age; the cerebral substance, as it increases, encroaching more and more upon the cavities within the hemispheres. The convolutions of the brain are not manifest externally until towards the fifth month, but they appear on the interior as early as the third. The corpus callosum, in the human fœtus, is never united before the third month.

A fact of great interest is worthy of being noticed in this place, viz. that the growth and developement of the embryo are sometimes arrested, so that certain stages, instead of being regularly succeeded by others more advanced, become permanent conditions, constituting that imperfect developement which exists in many monstrous fœtuses. It is a well-known, favourite opinion of some of the continental anatomists, that every period of fœtal life in man corresponds with the perfect developement of the organs in some of the inferior classes of animals, as birds, reptiles, and fishes; whence it would follow, that an organ in the human embryo, if arrested in any stage of its growth, must resemble the analogous organ in some of the classes abovementioned in its ultimate and highest developement. Thus, when the cerebellum is arrested in its growth, at the end of the third month, it remains small, as in reptiles. If the corpus callosum in the mammalia should not unite towards the end of the third month, it remains inappreciable, as in the three inferior classes of vertebrated animals. And in like manner, the tubercula quadrigemina of the mammalia resemble those of birds, when they cease to grow after the fifth month, i. e. remain hollow, and continue to be formed of two eminences only.

The cerebellum is said to grow from the fœtal age of two months, when it first appears, to the age of forty years, after which it gradually declines.

Such is the course of developement of the principal parts of the nervous system in the human embryo.

Vascular System. In the formation of the co-ordinate apparatus of the vascular system, the veins in the human embryo, as in the incubated egg, appear to be formed before the arteries; and the

first which are visible are said to be those of the umbilical vesicle. The developement of the veins in the ovum is similar to that of vessels in accidental tissues. Like the latter, they are at first only isolated vesicles, which at length become canals, and ultimately communicate with the general vascular system.

In the egg, and probably in the human ovum, the vena portæ, of which the omphalo-mesenteric vein is at first a principal branch, is the primitive trunk of the venous system. The umbilical vein is formed subsequently. The venæ cavæ also are not yet formed, nor indeed until the developement of the parts from which they convey the blood, and after the formation of the corresponding arteries. The inferior cava forms a communication with the umbilical vein by means of the canalis venosus, but the superior is independent of it.

According to Haller, the rudiments of the heart first appear in an irregular enlargement of the extremity of the vena portæ. Soon after, it bends itself into a semicircle, and presents three distinct enlargements, separated by two contractions. These dilatations correspond respectively with the left auricle, the left ventricle, and the commencement of the aorta. The contractions which separate them are at first of an appreciable length, but gradually disappear by the nearer approach of the vesicles towards each other. The narrow part between the auricle and ventricle is termed the auricular canal. The heart, it appears, therefore, though destined eventually to become double, is originally a single organ. It is at first situated in the neck, and in fishes it remains permanently in this place; but in the human embryo, it descends into the thorax, as the throat becomes developed.

The aorta, which constitutes the third dilatation, is the only artery which exists until the seventh week; and the appearance of the vesicle which is the first rudiment of it, proves that its formation is posterior to that of the veins. At the seventh week, the pulmonary artery appears, and directly joins the aorta, of which it appears like a root. At first it presents no division, but towards the eighth week, two small branches may be distinguished, which go to the lungs. Near its insertion in the heart, it detaches a branch which opens into the aorta, and which forms the ductus arteriosus. This canal, as well as the canalis venosus and the umbilical arteries, gradually become smaller as the time of birth approaches. The size of the branches which issue from the principal trunks, is in the ratio of the developement and volume of the organs which they are destined to nourish. Thus, the vessels of the liver are very voluminous, and the same is true of those which supply the thyroid and thymus glands, and the supra-renal capsules. The volume of these vessels is relatively much greater than that which they possess in the adult.

The *lungs* are not visible until towards the seventh week. At that period they occupy only the inferior part of the chest, below the heart, which much exceeds them in volume. They are whitish flattened bodies, lying very close to each other, with a very smooth continuous surface. Soon afterwards, a division into lobes takes place, and the lobes assume a granulated appearance. Towards the fourth month they become of a rose tint, which they retain until birth. Even at this latter period, they are still imperfectly developed, which is true also of the trachea and larynx. The diaphragm begins to appear in the third month, in the form of a thin membrane destitute of fibres. These appear about a month later.

The *trachea* is narrow and filled with a transparent fluid, and the parts of the larynx which are destined to become cartilaginous, are at this period membranous. The lungs are collapsed, forming a dense mass, which has the consistence of liver, and possesses a greater specific gravity than water.

The *intestine* is the part of the alimentary canal which appears the earliest. It is at first an oblong vesicle, lying against the vertebral column, which gradually prolongs itself in the two opposite directions, towards the cephalic and the coccygean extremities of the embryo, and thus forms a canal, which is imperforate at its two terminations. These are destined, at a later period of fœtal life, to become open, and to form the two terminal orifices of the alimentary canal, the mouth and the anus. The mouth becomes open the sixth week, the anus the seventh. It sometimes happens that the terminal developement of the intestinal canal is arrested before these orifices are formed, and the fœtus in that case may be born with an imperforate anus or without a mouth. The latter defect, however, is of very rare occurrence except in acephalous fœtuses.

The intestinal canal is at first very short, and continuous with the umbilical vesicle, and, together with the latter, is chiefly contained in the base of the umbilical cord. Its convolutions are formed at a later period, after it has attained the necessary length. At a period still later, it separates from the umbilical vesicle, and retreats within the abdomen. The intestinal canal, by means of lateral tubular processes, gives origin to the glandular bodies connected with it. Of these the most important is the liver. This is one of the most prominent organs belonging to the fœtus, and makes its appearance the third week of gestation, or, according to some embryologists, as early as the first. Towards the end of the first month, the liver occupies almost the whole of the abdomen, and its weight is equal to that of all the remaining part of the body. It extends at this time as low as the base of the pelvis, where the umbilical cord is implanted. The great relative

size of the liver diminishes progressively from the end of the fourth month, in proportion as the intestines increase and occupy a larger part of the abdominal cavity. At birth, the liver fills about one-half of the abdomen, and its weight is reduced to one-eighteenth of that of the body. The substance of this organ is originally almost of a fluid consistence.

The *gall-bladder* begins to make its appearance in the fourth month, and is formed by a tubular extension of the intestinal canal. It is at first empty; but about the fifth month it contains a little mucus, which, about the seventh month, gives place to bile.

The *spleen* becomes visible in the course of the second month of gestation. It is at first very small, particularly in comparison of the liver. In the tenth week, its size, compared with that of the latter organ, is as 1 to 500; in adults, as 1 to 5.

The *kidneys* appear in the seventh week. According to some embryologists, they are preceded by a substance called the Wolffian bodies, or false kidneys. In the ninth week, the kidneys are of an irregular elongated shape, and are formed by a union of little lobes or nodules, of which, in the tenth week, about eight are visible. At the time of birth, the number is found to have increased, as many as fifteen being distinguishable at this period. The cortical substance is not visible till about the sixth month. The ureters appear to originate from the kidneys, and to extend from these bodies to the bladder, for they are sometimes met with in the form of blind tubes, on their way to the bladder, which they had not been able to reach.

The *renal capsules* in the human embryo have a great relative size at an early period of gestation. In the seventh week, they are larger than the kidneys, and their absolute size increases until birth; but their relative magnitude gradually diminishes. In the fourth month, they equal the kidneys in size. In the seventh they are about one-half as large, and at birth only one-third.

The *bladder* is visible the fourth week. It is of an oblong cylindrical shape, is formed out of the allantois, and is continuous with the urachus. As the pelvis is very narrow during fœtal life, the bladder lies out of this cavity.

The parietes of the abdomen appear first in the sixth week, under the form of a transparent membrane.

Organs of Generation. The distinction of sexes in the fœtus becomes apparent about the fourteenth week.

The *testes* and *ovaria*, which are the fundamental organs of sex, are formed about the same time, at the inner and fore part of the false kidneys. About the seventh week they appear, as slender cylindrical bodies, lying below the kidneys. The uterus and the vesiculæ seminales are not formed so early. Their

first appearance may be dated from the eighth, ninth, or tenth week, a fact which has led some physiologists to the conclusion that the embryo before this period is of no determinate sex.

Testes. The testes are originally situated below the kidneys, behind the colon, and in front of the psoas muscles, covered anteriorly by the peritoneum. From the inferior part of each testis there descends a fold of the peritoneum to the internal ring, which is called the gubernaculum. A similar process from the ovaria is termed the round ligament. The testes gradually descend from their original position towards the abdominal ring, through which they are destined to pass into the scrotum. About the seventh month they reach the inner ring; in the ninth, their ultimate destination. The cause of their descent is not known.

The *epididymis* is formed on the testis about the tenth week; and a corresponding part on each ovary, which, however, soon disappears.

The *vas deferens* is a production of the epididymis, and the *vesiculæ seminales* of the vas deferens.

Uterus. Until the fourth month, the uterus has no body, but consists of a very thick neck and two cornua, which give attachment to the ovaria and the round ligaments. About the middle of the fourth month, the cornua of the uterus become less distinct, and the body of the organ begins to be visible. The Fallopian tubes also now begin to make their appearance. At the ninth month, the cornua have disappeared, the Fallopian tubes are long and tortuous, the fimbriæ are visible, and the vagina is very ample. The descent of these parts from the lumbar region into the pelvis has been ascribed to the contraction of the round ligament.

Muscles. These organs become visible about the third month; they are then of a soft or gelatinous consistence, of a whitish colour, and not distinguishable from their tendons. At first their fibrous structure is not manifest, but becomes perceptible by maceration in alcohol. But in the fourth and fifth months they are evidently fibrous, and of a redder colour, and are easily distinguished from their tendons, which have become whiter than at first. At this time, the muscles begin to exercise their functions in the production of sensible motions. These organs are not all formed at the same time. The first in the order of formation are those of the back and shoulders; and the muscles of the upper arm and thigh precede those belonging to the fore-arm and leg.

The bones. The bones originally consist of a gelatinous substance, inclosed in membranes. This jelly is gradually converted into cartilage, the change beginning at the surface, and proceeding inwardly. Cartilage first appears in the human embryo about the fifth week, in the bodies of the vertebræ, and in the ribs

and sternum. The process of ossification begins in the seventh week, and, according to Beclard, commences first in the cavicle, a point of ossification being visible in this bone at the end of the second month. The bones next in order are the lower and upper jaw, the femur and the humerus. In the first part of the third month, the frontal and occipital bones, the fore-arm, leg, scapula, and ribs, begin to ossify, and a little later, the temporal and sphenoid, the malar, parietal, and nasal bones; the vertebræ, carpus, tarsus, and third phalanges. In the fourth month, the vomer, the first and second phalanges, and the ilium; next, the ethmoid, lachrymal, and turbinated bones; and, in the seventh month, the os hyoides and ossa coccygis.

In several bones ossification begins at different points at the same time. In some there are two points in which the process commences, as the frontal bone, the vomer, and the under jaw. In the vertebræ and ethmoid bone, the ribs, the radius, tibia, fibula, and upper jaw, there are three such points; in the scapula, ulna, femur, os innominatum, and second and seventh cervical vertebræ, five; in the humerus, eleven; in the sphenoid, fourteen; in the sacrum, twenty-one. In the sternum the number is indeterminate. In the parietal, palate, malar, nasal, lachrymal, and turbinated bones, in the clavicles, patellæ, and in the bones of the carpus and tarsus, with the exception of the os calcis, ossification commences in a single point.

The bones of the fœtus are very vascular, and have a large proportion of animal matter. Hence they are of a reddish colour and possess some flexibility.

Eyes. The eyes and ears are productions of the brain. The rudiments of the former consist of a hemispherical mass at the extremity of the optic nerve, which forms the retina. The humours of the eye, however, do not originate from the retina; for they have been formed in cases in which this part did not exist. The sclerotica at first is very thin, and so transparent that the choroid coat is visible through it. The cornea, on the contrary, is opaque and very thick, but becomes thinner and transparent towards the sixth month. The vitreous humour is originally fluid, reddish-coloured and turbid, but gradually becomes more consistent and colourless. The crystalline lens when it first appears is globular, very soft, and of a milk-white colour. The pupillary membrane is a production of the posterior surface of the iris, and begins to appear the eleventh week.

The eyelids are formed about the tenth week, when their margins touch, and they adhere to the ball of the eye. The complete separation of the eyelids is accomplished in the eighth month.

Ears. The ear appears soon after the eye. This organ is a production of a hollow nerve, from the medulla oblongata, which

passes into the walls of the cranium. The membranous and cartilaginous parts are superadded by degrees afterwards. The cochlea and semicircular canals are formed by the beginning of the third month, and are covered by a membrane until the seventh month, at which time it disappears. The tympanum at first is very small, and is filled with a reddish-coloured gelatinous fluid. The ossicles appear the ninth week, as cartilages; they begin to ossify about the end of the third month, and the process is completed about the middle of the fifth. The ring of the tympanum is visible in the second month, and begins to ossify at the end of the third.

The external opening appears in the sixth week, as a little slit, which gradually extends inwardly until it reaches the membrana tympani.

Thyroid gland. This body has a greater relative volume in the fœtus than in the adult. At first it is composed of two isolated lobes; its tissue is softer, more copiously supplied with blood, and of a redder colour than after birth.

Thymus. The thymus gland, which is at first very small, begins to appear in the course of the third month, and grows rapidly until the time of birth; and indeed, it continues to increase in volume for two years after birth, but after this period it gradually shrinks, and finally disappears about the age of twelve years. Its developement is from below upwards.

Appendages of the Fœtus. These comprise the membranes and the fluids contained in them; the placenta and the umbilical cord; and the umbilical and allantoid vesicles.

The membranes which envelope the fœtus are three in number, viz. the decidua or epichorion, the chorion, and the amnion.

The *epichorion* is formed very soon after impregnation, by an exudation of coagulable matter from the inner surface of the uterus, and it exists even in Fallopian pregnancy, in which the ovum does not enter the uterine cavity. It is composed of a whitish albuminous matter, and presents the appearance of a false membrane. It forms a closed sac, every where adhering to the internal surface of the uterus, sometimes extending into the mouths of the tubes, and is filled with a semi-transparent rose-coloured fluid. At first it is composed of a single inorganic layer of albuminous matter, thrown out by the excited uterine vessels; but afterwards, according to some anatomists, it becomes organized, and divides into two distinct layers, of which the internal is the *caduca reflexa* of Hunter. Velpeau, however, contends that it always preserves the character of a mere inorganic concretion, wholly destitute of regular texture.

Such is the preparation made by the uterus for the reception of the embryo. When the ovum, conducted along the Fallopian tube, has arrived at the uterus, it encounters this membrane,

which obstructs its entrance into the uterine cavity. Unable to burst through this barrier, the ovum pushes the membrane before it, detaching it from a small portion of the walls of the organ, and gradually insinuating itself between the membrane and the internal surface of the uterus, to which it attaches itself. One important use of this membrane then, evidently is to confine the ovum, immediately after its entrance into the uterus, to the spot destined to be the seat of its implantation, which is generally in the fundus of the uterus. From this period, the decidua is evidently formed of two parts, continuous with each other; the outer and larger, lining the whole of the uterus except the part occupied by the ovum. The internal and smaller, forming a kind of indentation or cavity in the outer one, produced by the pressure of the germ, of which it forms the external envelope. The first of these is termed the *external* or *uterine decidua*, the other the *internal* or the *reflex*. The increase in dimensions of the former, will evidently be determined by the gradual enlargement of the uterus; while the increase of the latter will be regulated by the growth of the ovum. The cavity which separates them becomes continually smaller, until about the third or fourth month, when it is obliterated by the two membranes coming into contact, in which they continue during the remainder of gestation. At the close of pregnancy, the epichorion separates from the uterus, but continues to adhere to the chorion, from which, however, it may be easily detached.

The *chorion* is the most external of the proper membranes of the fœtus, and is situated between the epichorion and the amnion. It exists from the commencement of gestation. It is a thin transparent membrane, which adheres firmly to the placenta, covering all the vessels which run over its surface, and giving the ovum the appearance of a hydatid. When the ovum first enters the uterus, the chorion is remarkable for the numerous villosities of its external surface, whence it has been called the spongy or shaggy chorion. These villi are regarded by some anatomists as minute vessels, but Velpeau contends that they are composed of cellular filaments, or spongy areolæ, which at a later period serve for the developement of the vessels of the placenta on the portion of the ovum which touches the walls of the uterus, or corresponds to the root of the cord. In the first two months of gestation, these filaments appear over the whole surface of the ovum; but in the third month, they disappear every where except in the part where the ovum is connected with the uterus. According to many high authorities, the chorion is composed of two layers, but Hunter and Velpeau maintain that it is simple.

At the full period, the external surface of the chorion, covered by the epichorion and placenta, is reflected over the root of the cord, which it covers, as far as the abdomen of the fœtus. During

the first months of pregnancy, the capacity of the chorion is greater than that of the amnion or the internal sac of the ovum, and of course an interval exists between the two membranes, which is filled by a pellucid fluid. After the second month, however, the internal sac increases more rapidly than the external, in consequence of which the intervening space is gradually obliterated, the two membranes coming into contact, or being separated only by a thin sheet of jelly.

The *amnion* is the last or most internal membrane of the fœtus. It is thin, pellucid, and destitute of all appearance of either vessels or fibres. It forms a lining for the chorion, covers the placenta, and extends over the umbilical cord like a sheath, quite to the umbilicus, where it terminates.

During the first fifteen days of gestation, this membrane appears in the interior of the chorion under the form of a little vesicle, occupying but a small part of the cavity of the ovum. The growth is more rapid than that of the chorion, and in the course of the second month, it increases so much as to come every where in contact with the chorion, to which, at a later period, it contracts filamentous adhesions.

Velpeau remarks, that in the first month the amnion has no connexion, except with the umbilical cord, which appears to perforate it, in its passage towards the spine. But at a later period, when the parietes of the abdomen are formed, it unites with the epidermic layer of the fœtus, so as to make it difficult not to admit a real continuity between the two layers.

From the first period of gestation, the sac of the amnion is filled with a fluid in which the fœtus floats, and which is termed the liquor amnii. This fluid is of a whitish, milky, or yellowish colour, of a slightly saline taste, and of a sweetish and nauseous smell. It is composed of water, albumen, a caseiform matter, hydrochlorate and carbonate of soda, and phosphate and carbonate of lime. The caseous matter is the source of the unctuous varnish with which the body of the fœtus is found to be more or less thickly covered at the time of birth. At the end of gestation, the quantity of the amniotic fluid varies from six ounces to several quarts. Its average amount may be stated at about a quart.

The source of this fluid is not known; but it is generally supposed to be the product of an exhalation from the amnion, which is considered as analogous to the serous membranes; but some physiologists regard it as an excrementitious fluid, thrown out by the vessels of the skin.

Besides these large sacs, which envelope the fœtus, there are two small vesicles, denominated respectively the umbilical vesicle, and the allantois, which are found in most of the mammife-

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rous and cetaceous animals, connected with the ovum, and subservient to its nutrition, before it has attached itself to the uterus.

The umbilical vesicle. This is a little vesicle of a spheroidal or pyriform shape, situated between the chorion and amnion, and, about fifteen or twenty days after impregnation, about the size of a common pea. It is connected with the fœtus by a tubular pedicle, which before the formation of the abdominal parietes is continuous with the intestinal canal, apparently perforating the amnion, which divides it into two parts.

It contains a yellowish viscid or mucilaginous matter, analogous, as is supposed, to the yolk of an egg, and designed for the nutrition of the embryo, until the formation of the umbilical cord and placenta. The umbilical vesicle receives two small vessels, an artery and a vein, termed the omphalo-mesenteric vessels of the fœtus; the artery derived from the superior mesenteric; the vein from the vena portæ. At the expiration of a month it is diminished in volume, and gradually decreases for several weeks, and finally disappears at an uncertain period. The pedicle which connects it with the intestines remains tubular for four or five weeks, after which the canal is obliterated, the process apparently commencing at the umbilical end, and proceeding towards the vesicle.

The *allantois* is a little membranous pouch, lying between the chorion and amnion, near the umbilicus, communicating with the urinary bladder by a canal, termed the urachus. In the eggs of birds and of reptiles it communicates with the cloaca, in which the urinary canals terminate. In the human embryo it is said to appear in the fourth week, but its duration is short, and about the sixth week it almost wholly disappears. In the mammalia it acquires a great magnitude, and in some of them, as the carnivorous, ruminating, and solidungulous quadrupeds, it becomes so large as to inclose the whole amnion, and continues during the whole of fœtal life. In the human embryo it never attains a great magnitude.

It is not certain that, in the human embryo, the cavity of the allantois communicates with the urachus. Some embryologists even assert that the urachus is not usually tubular, though it is said to have been seen so in some instances as late as the third month; and Haller and Sabatier found it pervious on the side of the bladder even at birth. Lepelletier states, that many cases are mentioned in which the urine was discharged by this canal through the umbilicus, during the whole of life.

From its supposed communication with the bladder by means of the urachus, several physiologists have been led to the opinion, that the fluid contained in the allantois is urine, and that this pouch is nothing but a receptacle for this excrementitious fluid.

This opinion, however, rests upon a questionable fact, at least in the human embryo, i. e. the communication of the bladder and allantois, and has been generally rejected. Others are of opinion, that the fluid of the allantois is nutritive, and designed for the support of the embryo. The very existence of the allantois, however, in the human race, is denied by many physiologists.

The *umbilical cord* is a twisted cylinder, formed of vessels and a jelly-like substance, extending from the placenta to the abdomen of the fœtus, and forming the sole communication, during fœtal life, between the mother and the infant. It is chiefly composed of the umbilical vein, which performs the functions of an artery, conveying from the placenta to the fœtus the blood necessary to its growth; and by the two umbilical arteries, which perform the office of veins, carrying back to the placenta the residual blood. Besides these three vessels it contains a cellular or spongy tissue, filled with a gelatinous matter, and is covered by a membranous sheath, derived from the chorion and amnion. At an early period of uterine life, i. e. after the fifth week, it contains a part of the urachus or allantois, a portion of the intestines, the duct of the umbilical vesicle, and the omphalo-mesenteric vessels. But at about the end of two months, the intestines enter the abdomen, and the urachus, the vitelline canal, and the omphalo-mesenteric vessels become obliterated; and at this period the cord is composed of the three umbilical vessels, the gelatinous tissue, and the membranous sheath, as above described. According to Adelon, the cord does not appear until the end of the first month, the fœtus before this period being applied by its anterior face directly to the membranes. Velpeau, however, contends that this is an error, and that as early as a fortnight or three weeks after conception the cord is three or four lines long. At first the cord is a solid cylinder, destitute of a sheath from the amnion. It becomes tubular about the fifth week. It gradually lengthens towards the placenta, receives an investment from the chorion and amnion, and by degrees assumes the characters which it possesses at birth. Its length is very variable. Lepelletier says, that he has met with it in two instances only an inch and a half long, and it has been seen five or six feet in length. Its average length at birth is a little less than two feet. When very long, it is generally twisted about the infant's neck, and in some instances several times. Its size is equal to that of the finger. As the cord increases in length, its vessels gradually become contorted into a spiral. At first the vein is straight, occupying the axis of the cord, while the arteries wind spirally round it; and Hunter found the direction of the spiral, in twenty-eight out of thirty-two instances, to be from left to right; but Burns observes that the twist is generally from right to left. At length the vein as well as the arteries becomes twisted

and in the end the cord itself. The cord has been seen in one instance, implanted in the pericardium.

The *placenta* is a soft spongy body, formed essentially of the vessels of the chorion, connected by a cellular tissue, and it constitutes the principal connexion between the ovum and the uterus. It is a flattened body, of a circular or oval shape, with a diameter of from six to ten inches, a thickness of from one to one and a half inches, which decreases towards its edges; and having a dark red colour. It presents two faces, a fœtal and uterine. The first, which corresponds to the fœtus, is smooth and polished, and is covered by the chorion and amnion. The uterine face is unequal, being divided into lobes or cotyledons, separated by sulci, called sinuses. To these inequalities there are corresponding ones on the face of the uterus, to which the placenta is attached, and the parts are so disposed that the cotyledons of the placenta are lodged in the sinuses of the uterus, and *vice versâ.*

In certain classes of animals, the lobes of the placenta are completely isolated from one another, and in the human race they have no direct vascular connexion, each lobe receiving its own divisions of the umbilical vessels. If the placenta be injected from the umbilical vessels of the fœtus, the organ is rendered turgid with the injection, and its vessels are found every where filled; but between the ramifications of these vessels there always exists a substance which remains uninjected.

It appears also that the placenta consists of two portions, a maternal and a fœtal; the former furnished by the deciduous coat of the uterus, the other by the vessels of the chorion; and during the first three months, these portions may be separated from each other by maceration.

It appears also that it possesses two distinct and independent circulations, termed respectively the maternal and fœtal. In the former, the blood passes from the uterus to the placenta, and returns again to the uterus; in the latter, the fœtal blood is sent to the placenta and returns to the fœtus; and these two circulations are said to be wholly separate and distinct from each other; no direct communication by vessels existing between them.

If the umbilical vessels be injected, the injection does not reach the uterine surface of the placenta; and if on the other hand the uterine artery is injected, though the placenta becomes turgid from the distention of its own vessels, none of the injection passes into the umbilical vessels.

The want of isochronism between the maternal pulse and that of the umbilical cord, is another circumstance which is supposed to be inconsistent with the existence of a direct communication between the circulating systems of the uterine and fœtal portions of the placenta.

It appears, however, that physiologists have sometimes suc-

ceeded in injecting the fœtal placenta from the arteries of the mother, and the uterus from the vessels of the cord. Holland partly injected the fœtal portion of the placenta from the aorta, in a cat, and in a rabbit. Williams injected coloured oil into the ventral aorta in pregnant bitches, immediately after killing the animals by tying the trachea; and upon examination, the coloured oil was found in the umbilical vessels of several fœtuses; and on making incisions in different parts of the bodies of the latter, small globules of coloured oil could readily be seen on the surface of the blood which flowed from the incisions. In other experiments, the coloured oil was observed in the blood pressed out of the umbilical cord, after its division. These results were repeatedly obtained in Williams's experiments; and they certainly appear to establish the fact of a direct vascular communication between the mother and the fœtus, at least in the animals on which the experiments were made.

In a woman who died during pregnancy, Beclard succeeded in injecting the uterus from the vessels of the cord.

Velpeau, however, is of opinion, that in the generality of cases, even no utero-placental vessels, or vessels which pass from the uterus to the placenta, exist. He supposes that a pellicle or fine membrane is interposed between the placenta and uterus, which closes up the apertures of the uterine vessels, and that, if the maternal blood passes directly into the placenta, it must pass through pores, by a sort of imbibition. But he remarks, that the blood of the fœtus differs in its appearance and composition from that of the mother; and from thence draws the conclusion, that it undergoes some elaboration before it enters the placenta. The fœtal blood contains a greater proportion of serum, and is less coagulable than the blood of the adult; and it presents no difference of colour in the arteries and veins. At first it exhibits a rose colour, afterwards becomes red, and then dark or blackish. It appears also, from the microscopical observations of Prevost and Dumas, that the globules of the fœtal blood are so minute, that the ultimate vessels which transmit them would be incapable of receiving those of the adult blood, without great and perhaps fatal disturbance to the circulation. On the whole, the subject is in an unsettled state.

The umbilical cord may be implanted in any part of the placenta. In general it is inserted somewhere between the centre and circumference of the organ. From the point of insertion, the umbilical vessels diverge, ramifying over the surface of the placenta and dipping into its substance. In some instances the cord has been found attached to the membranes, the umbilical vessels branching over them on their way to the placenta.

The placenta is not formed until some time after the descent of the ovum into the uterus. The first rudiments of it may be seen

about the end of the first month. Velpeau, however, thinks that the formation of this organ commences with the arrival of the ovum in the uterus. It begins by separate vascular granulations on the ovum, which at first are distinct, but at length become grouped together, forming the commencement of the placenta. At first it covers a large part of the surface of the ovum, but afterwards it progressively diminishes relatively to the latter, in consequence of the increasing developement of the membranes. The placenta may become attached to any part of the internal surface of the uterus, even at the mouth, but its most usual place of insertion is at the fundus.

Nutrition. The nutrition of the fœtus is one of the most difficult and perplexing subjects in physiology, and various opinions have been entertained by physiologists with respect to the means by which it is accomplished. The sources of nutrition which have been principally indicated, are the umbilical vesicle for the first two months of fœtal life, and the placenta and the amniotic fluid subsequently. To these may be added the jelly of the cord, which is regarded by some embryologists as a source of nutrition to the fœtus.

The relative size of the umbilical vesicle, its very early appearance, its connexion with the intestinal canal of the fœtus previous to the formation of the umbilical cord, and its gradual diminution and final disappearance about the time of the developement of the umbilical vessels, together with the analogy which is supposed to exist between the contents of the vesicle and the yolk of the egg, have led to the opinion, that during the few first weeks the embryo derives its nourishment from this source.

That the amniotic fluid is a source of nutrition, is inferred from its containing an animal substance of a nutritive character, which exists in greater proportion at the commencement of gestation, and diminishes during the last months. Young animals it is said, may be nourished several weeks with this fluid. Another fact is, that fœtuses have in some instances acquired a considerable developement, though destitute of an umbilical cord. It is also asserted, that in some cases a fluid similar to the amniotic has been found in the mouth and alimentary canal of the fœtus. Even large quantities of it are said to have been met with in the stomach; and Heister, in a fœtal calf, which was dead and frozen, saw a mass of ice continued from the waters of the amnion quite to the stomach. It is a curious fact, that this fluid penetrates into the respiratory passages, the nasal, the tracheal, and the bronchial.

Others regard the waters of the amnios as an excrementitious fluid, secreted by the fœtus, and destitute of nutritive properties. They remark, that it may undergo great changes in its characters without injury to the fœtus, that the latter may continue to

live a considerable time after the entire evacuation of this fluid, and that the quantity of it is not diminished at the end of pregnancy, but, on the contrary, is sometimes very great at that period. They allege, also, the occlusion of the mouth during a certain period, the growth and nourishment of acephalous fœtuses, and the impossibility of swallowing without respiration, a function which does not exist during uterine life. The presence of the amniotic fluid in the alimentary canal, they regard as an accidental circumstance. The force of the latter objections, however, which are the most important, may be entirely evaded by supposing, what seems very probable, that the amniotic fluid is absorbed by the cutaneous vessels of the fœtus; and in support of this opinion, certain experiments of Van Bosch are adduced, who says, that in the fœtus of a mammiferous animal, upon opening the ovum immediately after it was extracted from the mother, he had found the lymphatics of the skin filled with the fluid of the amnios, and that, on applying ligatures to the limbs of a fœtus, and plunging them in the amniotic fluid, the lymphatics became full and very much distended. On the whole, it appears highly probable that the nutrition of the fœtus is derived in part from this source.

Placenta. But the most obvious source of nutrition in the fœtus is the maternal blood, transmitted from the uterus through the placenta; and notwithstanding all the difficulties with which this opinion, which is very ancient, is encompassed, it still appears the most probable. It is true, if we adopt the views of some distinguished physiologists, we should almost be led to believe that the placenta and umbilical cord, and even the umbilicus itself, instead of being instrumental in any functions important to fœtal life, were merely redundancies or ornamental appendages, lavished, we may suppose, by nature upon her unborn young, in the exuberance of her maternal fondness. Thus, it is said that a fœtus has been born alive without umbilicus, umbilical cord, or placenta, or any vascular connexion whatever with the mother. And Bartholin, we are told, during his travels in Italy, saw a person who had attained the age of forty years, who was born not only without an umbilicus, but also without anus or penis. The absence of the two latter appendages does not appear to make the case any stronger, for no one ever imagined that these parts were indispensable to fœtal life, however serviceable they are supposed to be to the adult.

The absence of the umbilicus or umbilical cord is a very remarkable fact, and in the instances in which it has occurred, is, perhaps, so far as concerns the placenta, decisive of the question of fœtal nutrition. It proves, that where this part does not exist, nourishment must be conveyed to the fœtus by some other channel; but it by no means proves that the cord is not a channel of

nutrition in cases *in which it does exist*, which are millions to one to those in which it does not.

It seems then to be ascertained, by a few cases, that a fœtus may be nourished, probably in an imperfect manner, without an umbilical cord, *if this part happen not to exist.* But what is the usual and established mode of nutrition in the immense majority of cases in which it does exist, is quite another question. Though it be true that in those extremely rare cases in which the cord is absent it cannot be essential to fœtal nutrition or fœtal life, it is no less true, that in the millions of cases in which it is present, mere pressure applied to it for a few moments will produce asphyxia and death. As an anomaly of structure exists in the former cases, it seems not absurd to suppose that an anomaly of function may exist also, especially in a function which there are such strong reasons for supposing is intimately related to the organ which is deficient. It is well known that persons rendered incapable of swallowing, by stricture of the œsophagus, may be imperfectly nourished for a very considerable but indefinite time by nutritive injections; and yet, notwithstanding such a thing is possible in the few cases in which the natural channel is not open, it is still true that the mouth, and not the rectum, is the part intended by nature for the introduction of nourishment.

The truth is, that there are certain eventual, or accidental functions, auxiliary to or vicarious of the primary ones, which under certain circumstances may perform the office of the former, though at other times playing a subordinate part or wholly quiescent. Thus, the circulation is performed in acardiac fœtuses by the vessels alone; the body is nourished during long fasting by the absorption of adipose matter; thirst may be quenched by the absorption of fluids by the skin; the principles of urine and bile are secreted by the cellular or serous tissues, when the glandular secretion is suspended; females sometimes menstruate from the lungs, nose, cheeks, or ends of the fingers, &c.

In like manner, it seems probable that though in the normal states the fœtus be nourished chiefly by the umbilical cord, yet in case this part happens not to be formed, and the introduction of nutriment into the fœtal system by this channel is thus cut off, it may obtain its nourishment wholly by the absorption of the amniotic fluid.

The mode in which the maternal blood reaches the fœtus through the placenta, and the residue is returned to the mother, involves no great difficulty, whether we suppose a continuity of vessels to exist or not. On the former supposition, every thing is plain; on the latter, it is easy to conceive that the arterial blood of the mother passes into the maternal portion of the placenta, and is there absorbed by the radicles of the umbilical vein; and flows to the heart of the fœtus; while the venous blood of the fœtus

conveyed to the placenta, is absorbed by the veins of the maternal portion, and mixed with the general mass of the venous blood, is transmitted to the lungs of the mother.

The want of isochronism in the maternal and fœtal pulse, is a circumstance of no weight against the doctrine in question, for, since the pulsatory motions of the arteries disappear in the capillary vessels, it is impossible that they should be transmitted through the vessels of the placenta. The maternal blood must enter the fœtal circulation in a uniform current, and on reaching the heart receive its future impulses from this organ.

On the whole, it appears probable that in the first weeks of gestation, the nutrition of the embryo is derived from the fluid contained in the umbilical vesicle; that in the first part of fœtal life, the amniotic fluid contributes to the same object; but that during the whole period of gestation, from the formation of the umbilical cord, and the appearance of red blood in the embryo, the principal source of nutrition is the maternal blood transmitted through the placenta, and entering the fœtus by the umbilical cord.

Fœtal circulation. The parts concerned in the fœtal circulation are the umbilical vein, the heart, the pulmonary artery, the aorta, and the umbilical arteries.

1. The *umbilical vein,* which performs the office of an artery, since it conveys to the fœtus the blood employed in its nutrition, originates in the substance of the placenta, by extremely delicate roots, and emerging from the placenta, and passing along the cord, enters the abdomen, and penetrates into the liver by the longitudinal groove, distributes eighteen or twenty considerable branches to this organ, particularly its left lobe; afterwards pursues its course, and divides into two branches, one of which opens into the sinus of the vena portæ, and the other, taking the name of the *venous canal,* into the vena cava inferior.

The *fœtal heart* exhibits certain peculiarities of structure, essentially connected with the phenomena of the fœtal circulation. The septum between the auricles is perforated by a large opening, called the *foramen ovale,* forming a free communication between the two auricles. And in the right auricle is found a membranous fold, called the Eustachian valve, which is supposed to isolate the two currents of blood entering by the superior and inferior cavæ, and to direct the former towards the orifice of the right ventricle, and the latter through the foramen ovale into the left auricle.

The *pulmonary artery* instead of being distributed wholly to the lungs, divides into two principal branches, one of which is spent on the lungs, while the larger branch, under the name of the *ductus arteriosus,* proceeds to the aorta, into which it opens, below the curvature of this vessel, thus forming a second communica-

tion between the two principal divisions of the circulation, the venous and the arterial.

The *aorta* receives part of the blood of the pulmonary artery by the *ductus arteriosus*, but in other respects does not differ from the same vessel as it exists after birth.

The *umbilical arteries* originate from the hypogastric, pass out of the abdomen by the umbilicus, and entering the umbilical cord, proceed to the placenta, in which they terminate by capillary ramifications. From the structure and disposition of the parts above mentioned, the peculiarities of the fœtal circulation will not be difficult to comprehend.

The uterine arteries of the mother convey arterial blood to the placenta, whence the radicles of the umbilical vein receive it, either by continuity of vessels, or by absorption. By the umbilical vein it enters the abdomen of the fœtus, and is divided into three portions, the first of which is sent directly to the liver by the branches which have already been mentioned; the second also enters this organ by mingling with the portal blood; the third portion enters the vena cava inferior by the ductus venosus, and passes to the right auricle of the heart, its current being directed, by the disposition of the Eustachian valve, towards the foramen ovale, through which it is propelled, by the contraction of the right auricle, into the left. From the left auricle it passes into the left ventricle, thence into the aorta and the great branches which spring from its arch, viz. the carotids and subclavians. By these vessels the head, neck, arms, and upper part of the thorax, receive their blood; and the residual fluid returns by the vena cava superior, which deposits it in the right auricle. The stream of blood entering the auricle by the superior cava, directed by the Eustachian valve, crosses the current of the inferior cava, and passes into the right ventricle, thence into the pulmonary artery, where it is divided into two principal streams, one of which is transmitted to the lungs by the divisions of the pulmonary artery, while the other and larger stream enters the aorta below its curvature, by the ductus arteriosus. This blood is transmitted by the branches of the abdominal aorta to the abdomen and the inferior extremities; while a smaller part returns to the placenta by the hypogastric arteries, and is distributed through this organ by capillary vessels. From these it is received by the radicles of the uterine veins, and by them returned to the maternal circulation.

The functions of the foramen ovale, and of the ductus arteriosus, are evidently to establish a free communication between the two sides of the heart, and between the pulmonary artery and aorta, in this manner to reduce the double heart provisionally to the condition of a single one, and to unite the force of both ventricles upon the aortal circulation. The left auricle receiving

scarcely any blood from the lungs, could furnish no supply to the left ventricle but for the foramen ovale; and on the other hand, the lungs being inactive, and receiving but little blood, the greater part of the blood of the pulmonary artery is transmitted to the aorta through the ductus arteriosus, by which disposition, the united force of both ventricles is employed in propelling blood into the aorta.

If it be true, that the two streams of blood, entering the right auricle at the same time by the superior and inferior cavæ, decussate each other without becoming blended together, (an opinion, however, on which physiologists are not agreed,) the blood of the inferior *cava* passing through the foramen ovale into the left auricle, and thence into the aorta, while the stream from the superior cava, crossing the former in the right auricle, is directed by the Eustachian valve into the right ventricle, whence it passes into the pulmonary artery, and the greater part enters the aorta *below* the curvature, by the ductus arteriosus, it will follow that the parts which are nourished by the vessels which spring from the arch of the aorta, viz, the head, neck, superior extremities, &c., must be supplied with a blood richer in nutritive principles than that which is distributed to the parts below the diaphragm. For the arch of the aorta, and the vessels which spring from it, on this supposition, are replenished with blood fresh from the maternal circulation; while the abdominal aorta, which is supplied in a great measure by the pulmonary artery, contains the impure residue of the blood which had been previously transmitted by the vessels of the arch of the aorta, to the head, neck, upper extremities, &c. This view of the fœtal circulation will throw some light upon the great comparative developement of the head and superior extremities, and the extraordinary dimensions of the fœtal liver.

Gravid Uterus. The progress of gestation, and the increasing volume of the contents of the uterus, are accompanied with a corresponding enlargement and developement of this organ. In its progressive increase in size, it constantly preserves nearly the same thickness, and such a relative capacity as never to be rendered tense by the volume of its contents.

In the second month, the uterus enlarges in every direction, preserving nearly the same shape. At the end of three months, its length, measured from the mouth to the fundus, is about five inches. In the fourth month it rises somewhat higher, measuring about six. In the fifth month it rises out of the pelvis, and rests against the front of the abdomen, rendering it tense, and feeling like a ball. At this period it extends half-way between the pubis and umbilicus, and its length, from the cervix to the fundus, is about six inches. In the progress of its enlargement the distinction between the cervix and body is lost by the develope-

ment of the former. At seven months, it reaches the umbilicus, and its length is about eight inches. In the eighth, it extends upwards half-way between the umbilicus and sternum, and the cervix is completely effaced; and in the ninth, it almost reaches the lower point of that bone, and is ten or twelve inches in length.

During gestation the position of the uterus is not vertical, but oblique, the mouth of the organ being directed backwards, and the fundus inclining forward towards the abdomen. The os uteri is closed very perfectly by a tough glutinous matter, secreted by glandular follicles seated on the inner surface of the cervix.

Labour. The ordinary duration of utero-gestation is about forty weeks, at the end of which period the fœtus escapes from its confinement, and enters upon a new sphere of existence. The causes which occasion the expulsion of the fœtus, are chiefly two, viz. the contraction of the uterus, and the powerful action of the abdominal muscles and diaphragm. These contractions are accompanied with severe recurrent pains, and at a certain period of the process, they occasion a rupture of the membranous envelopes of the fœtus, and an evacuation of the amniotic fluid; after which the contractions of the uterus act directly upon the fœtus, the head of which passes into the pelvis, traverses this cavity, and is soon felt pressing upon the perineum, over the internal surface of which it glides, and distending the os externum to the utmost, is at length ushered into the world. The birth of the head is followed immediately, or after a brief interval, by that of the body of the infant.

After the birth of the child, the mother usually remains free from pain for several minutes, or even much longer; but in general the pains are renewed in a short time, and the result of them is the expulsion of the placenta and membranes. The removal of the placenta is succeeded by more or less hemorrhage, which gradually diminishes, and is succeeded by a serous discharge, termed the lochia, which continues several days; the uterus in the meanwhile gradually contracting to its usual size.

The ordinary duration of labour is from four to six hours, but it sometimes comes on suddenly, and is completed in a few minutes; and in some instances, on the contrary, it is protracted several days.

It is commonly preceded two or three days by a discharge of mucus from the vagina, and slight pains in the abdomen and small of the back, and by a tumefaction and relaxation of the external parts. The ligaments of the pelvis participate in this relaxation. The uterus also subsides in the abdomen a few days before parturition.

The process when once commenced, may be divided into three stages, viz. the dilatation of the os uteri, the expulsion of the child, and that of the placenta and membranes.

The first stage is generally of longest duration. It is accompanied by frequent pains commencing in the small of the back, and apparently extending to the neck of the uterus, or towards the upper part of the thighs. These pains are sharp and cutting, last from half a minute to one or two minutes, and recur at intervals of from a quarter to half an hour. Every pain is accompanied with a contraction of the body of the uterus, a tension of its neck, and a dilatation of its mouth. These pains gradually increase in severity and duration, the uterine contractions become more energetic, and the dilatation of the mouth of the uterus at length considerable.

This ushers in the second stage, which frequently commences with the rupture of the membranes, and discharge of the waters of the amnios. The discharge of the waters enables the uterus to contract to a greater degree, and to exert its contractile power upon the body of the fœtus. The pains now change their character, are felt more in front, are more protracted, and attended with a feeling of bearing down. They are evidently expulsive, and are accompanied with a straining and strong contraction of the abdominal muscles like that which is exerted in evacuating the rectum. The female voluntarily favours this expulsive action by holding her breath, and exerting all the muscular effort of which she is capable. Under this powerful action, the head descends into the pelvis, and begins to press upon the perineum, while the os externum is put on the stretch. As the pressure from the uterine contractions increases, and the pains become more unintermitting, the perineum protrudes, becomes very thin, and is tensely stretched over the head of the child. A strong expulsive effort, attended with very severe pain, accomplishes the delivery of the head, which is soon followed by that of the trunk of the child. A ligature is then applied to the cord, a short distance from the umbilicus, and the cord is divided. The birth of the child is followed by a short period of complete relief from pain. In a little while, however, the contractions of the uterus recommence, attended with moderate pain, and soon accomplish the expulsion of the placenta and membranes. A discharge of blood succeeds, and sometimes precedes, the delivery of the placenta.

The moment the child is born, it dilates its chest, inhales air into its lungs, and announces its arrival into the world by cries.* As soon as respiration is established, the lungs, distended by air, permit the blood of the pulmonary artery to penetrate them. The ductus arteriosus gradually contracts, and at length becomes

* I was informed some years ago by a professional gentleman of high standing, that he once knew a child which it was necessary to deliver by the crotchet, and from whose cranium its contents were almost wholly evacuated, cry lustily as soon as it was ushered into the world.

obliterated; and the left auricle, now receiving blood from the lungs, can no longer admit the blood of the right auricle through the foramen ovale, which also closes up. The umbilical vein and arteries also, their function of conveying blood to and from the placenta having ceased, degenerate into a kind of fibrous ligament.

Theories of Generation.

Of the intimate and essential nature of the process of generation we are wholly ignorant. Innumerable hypotheses have been formed on the subject, but no satisfactory theory has yet been framed; and, considering the nature of the subject, none perhaps is to be expected. Some of the most prominent opinions which have been presented to the world, by ancient and modern physiologists, will here be noticed.

The theories of generation have differed according to the ideas which physiologists have entertained of the nature of the spermatic fluid, and of that of the matter furnished by the ovaria of the female.

The seminal liquor by some physiologists has been considered as a fluid composed of the elements of each of the different parts of the human body, and as destined to reproduce every one of these parts in the formation of the embryo; by others as a vehicle, containing animalcules, some of which, after undergoing several metamorphoses, are destined to be elevated to the rank of the beings by which they were produced; by a third class, as a vivifying principle, designed to impress upon the germ the first movements of life and developement.

In regard to the matter furnished by the ovaries, the same differences of opinion exist. According to some, it is a vesicle filled with a spermatic fluid, formed, like that of the male, out of the elements of every individual part of the body; or it is a vesicle destined to serve as a nidus to the spermatic animalcule, or to furnish it with nutritive matter. Some regard it as an amorphous substance, possessing a gelatinous nature, which renders it fit to receive the principle of life, and of organic developement; others consider it as a germ, a pre-existing ovum, in the female, having the aptitude to form, under the prolific influence of the male fluid, an individual similar to that which furnished it.

The numerous theories which have been formed from these assumptions, have been usually classed under two general heads, the theory of *epigenesis*, and that of *evolution*.

I. *Epigenesis.* The theory of epigenesis implies, that the new individual is wholly formed out of molecules of matter, furnished by the two sexes. A peculiar unknown power, differing from the general forces of matter, presides over the union of these mole-

cules, and their organization into the new individual, and bestows upon the latter all its properties. Physiologists, however, have differed much in the mode in which they have conceived of the doctrine of epigenesis, and the application which they have made of this system.

According to Hippocrates, each sex has its own semen, a fluid formed out of materials derived from all parts of the body, and especially the nervous parts. In generation these two fluids are mixed in the uterus, and by the influence of the heat of this organ, form, by a kind of animal crystallization, the new individual. According to Hippocrates, each semen, that of the father and that of the mother, is composed of two parts, one strong, and the other weak; the union of the two feeble parts produces a female, that of the two strong parts a male. The child resembles the father or the mother, according to the predominance of the male or female semen.

According to Aristotle, the female does not contribute a seminal fluid in generation, but the menstrual blood. This forms the basis of the new individual; and it is the male fluid which gives it form, and impresses upon it a vital movement.

The doctrine of Hippocrates, in a modified form, has been adopted by various modern physiologists. Descartes attributed the formation of the new individual to a fermentation of the two seminal fluids of the male and female; Pascal, to a chemical combination of the male semen, which he supposed to be acid, with that of the female, which was considered to be alkaline.

The celebrated naturalist, Buffon, revived the old doctrine of Hippocrates in a modified form. According to Buffon, there exist in nature two kinds of matter, one living, the other dead. The first consists of an infinite number of minute, incorruptible particles, which Buffon calls organic molecules. These molecules, in combining in greater or less numbers with dead matter, form all organized bodies; and without ever being destroyed, they pass incessantly from plants to animals by nutrition, and return from animals to plants by death and putrefaction.

These molecules, according to Buffon, compose the chyle, and the aliments out of which the chyle is formed. They are employed in forming all the organs of the body, in their nutrition and growth. If they are too abundant in certain parts of a living body, they may give rise to spontaneous productions and parasitic animals, as hydatids, worms, and insects. Oftentimes they unite together and become organized out of living bodies; and then they form true organized beings, without sexual generation. As long as a living being continues to grow, all the organic molecules are employed in its nourishment and developement. But when it has attained its full growth, while it is still young, and full of life and vigour, these molecules being too abundant

for the ordinary wants of the individual, accumulate in the testicles and the seminal vesicles of the male, and in the ovaries of the female; and in the anthers and the receptacle of plants; and the result is the formation of the pollen of plants, the spermatic fluid of male animals, and the corpora lutea of the ovaries in females, and the *cicatricula* of eggs in oviparous females.

As these organic molecules, always active and always living, circulate equally in all parts of the body, all the organs and humours are impregnated with them; and as soon as they exceed the quantity required by the wants of the organs or fluids, the excess is immediately conveyed from each part to the common reservoir, where they are collected together. Of course, the male semen contains organic molecules from all parts of the body of the male; whence it is easy to conceive that the new animal, formed from this semen, must resemble its father. In like manner, the corpora lutea of the female ovaria are composed of organic molecules of every organ of the female, and in fact, contain a kind of *extract* of the whole body of the female; and consequently, the new animal, formed out of the combination of the corpus luteum of the female and the semen of the male, ought to resemble, at the same time, both its parents. The molecules of similar parts in the two sexes unite together. Those for example, which come from the eye of the father, combine with those derived from the eye of the mother, and so of all the other organs. The sex of the fœtus will be determined by the predominance of the male or female semen in the mixed fluid, which produces the young. A similar cause will determine its greater resemblance to one of its parents than to the other. Buffon also supposes, that every plant and animal forms a mould in which organic molecules are collected together, and become organized.

This whole system of generation, it will be perceived, is mostly a tissue of ingenious hypotheses, wholly destitute of proof. The organic molecules, the moulds formed by different animals and plants, the vesicles of the ovaria being filled with semen, this semen being an extract of all the organs and fluids of the body; all these are mere assumptions, wholly destitute of evidence, and even of probability.

II. *Evolution.* This system supposes that the new individual pre-exists, in some form or other, in one of the sexes, that it is animated by the influence of the other sex in generation, and then begins a series of developements, the result of which is to form an independent being. The partisans of this system are divided into two sects, viz. the *ovarists*, and the *animalculists.*

The ovarists ascribe the principal share in generation to the female; and they assert that the part contributed by the female is an egg, which they define to be an organized substance, formed

of an embryo, and of particular organs, destined to subserve the nutrition and the first developements of the embryo, and fitted to become after a series of these developements, an individual similar to that from which it sprung. This system was derived from observation of oviparous animals, in which the female furnishes an egg, and in many of which this egg is laid before copulation, and is fecundated out of the body. This disposition was extended by analogy to oviparous animals, and hence the celebrated saying of Harvey, *omne vivum ex ovo.*

This theory was supported by many considerations, among which are the following:—1. The pre-existence of the germ before fecundation in many organized beings. In plants, for example, the rudiments of the seed exist in the flower before the pollen, destined to fecundate it, has arrived at maturity. In birds, eggs exist in the female before copulation, and are sometimes laid by virgin birds. In fishes and some of the reptiles, the egg is not fecundated until it has been excreted from the body; and Spallanzani affirms, that he has seen the rudiments of the tadpole in the unimpregnated eggs of the frog; and Haller says the same with regard to the hen's egg.

2. Another consideration is the curious fact, that in some species of animals, a single copulation is sufficient to give fecundity to many successive generations. Now, in order that several generations should thus be fecundated by a single copulation, it seems to be necessary that the germs from which they are derived, should pre-exist in the first.

3. Another fact, in favour of the same view, is the involution of germs in many plants and animals. Thus, the bulb of the hyacinth contains, ready formed, the rudiments of the flower which is destined to spring from it. In the buds of trees, also, may be seen, folded up, extremely minute branches, leaves, and even flowers. In the jaws of certain animals the germs of several series of teeth are visible. In the volvox, a transparent animal, may be seen several young inclosed in one another, like a nest of boxes; sometimes an egg is found inclosed in another, and fœtuses have been discovered, in several instances, contained in the human body.

4. Further; in frogs and insects, animals which undergo a striking metamorphosis, it is observed that the forms which they successively assume, are evidently contained in those which precede them. The young frog may already be discovered under the skin of the tadpole; the lineaments of the future butterfly are distinguishable in the chrysalis, and those of the chrysalis in the caterpillar. The minute quantity of semen which is sufficient for impregnation, furnishes another reason for believing that this fluid can contribute nothing more than a vivifying influence to the materials furnished by the female.

Several objections have been made to the theory of the ovarists: 1. First, the resemblance of the young to the father. This resemblance is sometimes so great, that it seems to contradict the idea of a pre-existing germ in the ovum. For example, men with six fingers on a hand, frequently beget children distinguished by the same peculiarity; and many other peculiarities of the father may in the same manner be transmitted to the child.

2. The existence of hybrid plants and animals, proves the great influence exerted by the father upon the qualities of the fœtus. The child of a black father by a white mother has a colour intermediate between the complexions of his two parents; and if the successive generations of the offspring of a white woman be united to negroes, they will, at last, lose all trace of the primitive colour of their race, and become perfect negroes.

3. It has also been objected to the theory of pre-existing eggs, that the lapse of time is incessantly producing changes in the species of plants and animals which live at the surface of the earth. Linnæus was of opinion that there existed in his day more plants than in ancient times, and of course that new species of vegetables were formed. Lamarck supposes that all plants and animals are continually changing by the influence of climate, season, domestication, and the crossing of breeds; and the reason that the existing species appear permanent is, that the circumstances which modify them require an enormous time to act, and the life of one man is too short to enable him to witness these changes. This opinion of Lamarck is in harmony with that which he has broached relative to the origin of organized beings; the vital movement, as he supposes, always having the effect of making the organization more and more complicated, and consequently producing incessant changes of species.

The ovarists are divided into three classes. One class supposes that the ova, or germs, are disseminated throughout space, and only develope themselves when they penetrate into bodies capable of retaining them, and causing them to grow; i. e. beings similar to themselves. This is called the system of *panspermy*, or *the dissemination of germs.* A second class hold, that the ova are inclosed in one another, in a series, and developed, one after another, by successive generation; so that not only the ovaria of the first female contained the ova of all her own offspring, but a single one of these ova contained the whole human race. This is the celebrated system of the *involution of germs.* A third class of ovarists maintain that every female forms her own ova, by a kind of secretion.

The other sect of the advocates of the system of evolution are called *animalculists;* a name derived from the minute animalcula existing in the male semen. In 1674, Ham, and Lewenhoeck, and Hartsæker discovered in the semen of animals a prodigious

number of small bodies, which, from their motions, they inferred to be animals; a discovery which gave rise to a new system of generation, viz. that of spermatic animalcula. It was supposed that these minute animals, after undergoing a series of metamorphoses and developements, were at length formed into new individuals. As in the system of the involution of germs, the first woman is supposed to have contained the whole human race, in this system it is the first man that contained all succeeding generations, the spermatic animalcule being the pre-existing germ, the organized homunculus, in which the whole future race was inclosed.

It appears that spermatic animalcules exist in the semen of all animals, and that they are not found in any other animal fluid. It also appears that they differ in different species of animals, but in the same species are always alike. They exist in the semen only during the age when generation is possible, and are absent both in the first and last periods of life. Their number is so great that a drop of the seminal fluid of the cock, not larger than a grain of sand, contains no less than fifty thousand. The extreme minuteness of these animalcula affords one means of explaining the fact, that Spallanzani was able to effect artificial fecundation with very minute quantities of seminal fluid.

Assuming, then, that spermatic animalcula are the rudiments of the new individuals, Lewenhoeck says, that when projected into the uterus they attract the ova, and convert them into real embryos. Andry supposes that they crawl through the Fallopian tubes, reach the vesicles of the ovaria, in one of which a single animalcule incloses itself, then returns with it to the uterus, and begins to develope itself, by means of the nutritive matter contained in the ovum. Spallanzani regarded these animalcules as analogous to the infusory animalcula; and Buffon considered them as his organic molecules.

More recently, Dumas and Prevost have recalled the attention of physiologists to these minute animals. They not only assert their existence, but they consider them as the direct agents of fecundation, and as bestowing upon the semen its aptitude for this office. By the aid of the microscope they discovered them in the semen of all the animals which they examined, the number of which was very great. They were discovered, not only in the semen just excreted by living animals, but also in the fluid taken, after death, from the vas deferens and from the parenchyma of the testicles. But they were not found in any other fluid of the body, not even in the other humours secreted by the sexual organs, as the liquor of the prostate gland, that of the glands of Cowper, &c. In animals of the same species these animalcula were observed to resemble one another in shape, size, and motion; but in those of different species they were alike in these respects.

They executed spontaneous motions, which, in the semen obtained during life, by ejaculation, gradually ceased in two or three hours; but in that which was taken from the spermatic vessels after death continued only fifteen or twenty minutes; but if the semen was left in its proper vessels after death, the motions continued eighteen or twenty hours. These animalcules exist in the spermatic fluid only when generation is possible. In birds, with the exception of the cock and pigeon, they are found in the semen only at the season fixed by nature for copulation in these animals. Another curious fact is, that they appear to be influenced by the physiological state of the animal which furnishes them. Their motions are rapid and brisk, or languid and slow, according as the animal is young or old, in a state of health or disease. In their researches upon the ova of the mammalia, Dumas and Prevost observed the animalcules filling the cornua of the uterus, and remaining there, alive and in motion, until the descent of ovula into these organs, after which they gradually disappeared. The seminal fluid loses its prolific power in about twenty hours, and in the same interval of time the animalcules contained in it gradually cease their motions and perish. If the semen be evaporated to dryness, and afterwards diluted with water, it loses its fecundating power. Dumas and Prevost found also that when the animalcula were killed by repeated electric shocks sent through a liquor impregnated with semen, this liquor lost its prolific powers.* In another experiment, having separated the animalcula by filtration, the liquor which passed through was found to be incapable of effecting fecundation, while that which remained on the filter retained this power. Spallanzani had before obtained the same result with the water with which the filter was washed. From these facts, Dumas and Prevost infer, that the spermatic animalcules are the immediate agents of fecundation; and they conjecture, that the animalcule forms the nervous system of the new individual, while the ovum furnishes only the cellular matrix in which the organs are formed.

Perhaps all that can be logically concluded from the researches of Dumas and Prevost is, the existence of animalcules in the spermatic fluid, and the active part which they take in fecundation.

Bourdon is disposed to adopt the system of the pre-existence of germs in the ova of the female; and he observes, that the new being appears first inclosed in the ovum, when detached from the ovaria of the mother. And since it is surrounded from its first appearance with several membranes, it seems probable that the

* Spallanzani, however, according to Bourdon, took some of the semen of reptiles, carefully destroyed the animalcules in it, and yet fecundated the ova which he moistened with it. And Bourdon affirms, that semen, deprived of all its visible animalcula, still enjoys the power of fecundating the ova of the female.

ovum contained originally, if not the fœtus wholly formed, at least the rudiments of the embryo and its organs. The first lineaments of the new animal are already indicated, by a white spot in the unimpregnated egg of birds; and these first traces of organization are still more evident in the ova of some of the reptiles. That the germ is not visible in every ovum is no proof that it does not exist, because every organ exists first in a fluid state, and every fluid which is perfectly transparent is invisible. In proof of this it is worthy of remark, that the organs which first manifest themselves, have, from their first appearance, a considerable volume; a fact which makes it probable that they existed in another state before they became visible; and that, instead of being formed by degrees, and spontaneously, they had only undergone a kind of metamorphosis.

But if the germs, although invisible, really pre-exist in the ova of the female, it seems to follow that these first germs must contain new ones; and, in fact, that all the individuals of the same species must be contained in the ova of the first female of this species; in other words, the pre-existence of germs in the ova of the female, seems unavoidably to infer the indefinite involution of germs. This supposition is beset with difficulties, which appear insurmountable; but Bourdon thinks that the doctrine may be conceived of in a manner which will elude them, or destroy their force.

Every germ, he says, contains all the elements of the organs of the new animal; but, it contains them only in a latent state, in the state of primitive elements, not yet characterized and manifest. Under the form of a transparent fluid, whose parts are invisible, there exist the principles by means of which the whole future animal is to be formed and organized; and since the principles or rudiments of all the organs exist in this colourless fluid, the lineaments of the ovaries must be present there likewise, as well as the elements of all the other organs; and as these ovaries contain new ova, and these ova in their turn contain the preformed elements of the future embryo, it is apparent that all these organs contain in their turn, and simultaneously, the lineaments or rudiments of the beings which are successively to appear; since each germ contains all that is necessary to constitute a new being, and of course, the rudiments of the ovaries, as well as of all the other organs. In short, every ovum contains a germ; every germ is composed of the elements of a new being; and the ovaries are represented in this assemblage, as well as all the other organs. Now, every ovary contains numerous ova, each one of which contains the rudiments of new ovaries, new ova, and new germs. This theory, therefore, only supposes the existence of a first germ, containing all the principles necessary to the formation

and perfect organization of a single embryo. All the rest of the system flows naturally from this one principle.

Many objections it is true have been made to this theory. It has been asked, whether it be possible to conceive of this infinite series of bodies, inclosed one in another, from the time of the creation until the final extinction of the species. But this, according to Bourdon, is too gross and material a view of the subject. These germs in each species, he considers, not as consisting of material elements, but merely as an aptitude or predisposition to engender them. The supposition that every new being has its primitive source in the ova of the female, is by no means inconsistent with the admission, that the male fluid must influence the germ, and of course is not at variance with the fact of the resemblance of children to their fathers.

Another objection is founded on the successive appearance of the organs, their changes of form, their complications, &c. For, if the organs appear successively, if they change, become more complicated or more simple, they cannot have a contemporaneous origin, and their elements cannot have been preformed. In support of this argument it is alleged, that the heart of the mammalia and birds, at first have only a single ventricle and a single auricle, and that they acquire successively the parts which are wanting when they at first appear. It is also alleged that the organs are at first divided, or are formed in pieces, and that the materials of them are more numerous than they appear in the organ when completed.

On the whole, the objections to the doctrine of the pre-existence of germs are so strong, that most physiologists of the present day have adopted the theory of epigenesis, according to which, the seminal fluid of the male is united to a material furnished by the ovarium of the female, and the embryo is formed by the union of the two; and both of the material elements of generation, furnished by the two sexes are the result of a secretion from the ovarium in the female, and from the testicles in the male.

CHAPTER XXX.

DYNAMIC CONNEXION OF THE FUNCTIONS.

Besides the common bond which connects all parts of the living animal machine into one complex whole, establishing a mutual connexion and subordination of all its constituent parts

and functions, there are certain special associations between certain organs, by means of which the condition of one modifies that of the sympathizing organ, or both conspire in their actions towards the same common object. The first of these relations is denominated *sympathy;* the second, *synergy;* although both are frequently comprised together under the former appellation. The organs of sense, the stomach, the diaphragm, the abdominal muscles, the heart, brain, uterus, and mammæ, and the intestinal mucous membrane, are the organs or parts, which are most frequently the starting point or the term of the sympathies.

Synergy. Of the association of different organs or parts towards effecting a common object, a few prominent examples will be mentioned.

In the organs of sense, especially the eye and the ear, we find several examples of this synergy or catenated action.

Eye. In the eye, the motions of the iris are associated with luminous impressions on the retina, in such a manner as to regulate the quantity of light admitted into the eye, according to the force of the impression made upon the retina by the rays, while the direct incidence of light upon the iris itself causes but little if any contraction of the pupil. The eyelids are associated in the same function, and co-operate with the iris in regulating the quantity of light admitted into the eye. In this case we have an example of muscular action of an organ catenated with the sensible impressions made upon a different part of the same. But there is also a harmony of action between the two eyes themselves. For the corresponding muscles of these organs act simultaneously, and in a similar manner, in the ordinary exercise of vision; and a loss of this harmony constitutes the disease called strabismus or squinting. From the same cause, the impression of light upon either eye causes contraction of the pupils of both. This synergy is also illustrated by certain morbid affections of the organ of vision. Thus, in amaurosis of one eye, the oscillations of the iris in the sound organ sometimes excite corresponding motions in that of the diseased eye, though wholly insensible to luminous impressions. In like manner, in inflammation of either eye, light is painful to both.

Ear. A similar association exists between the impressions upon the auditory nerve in hearing, and certain muscular actions subservient to this sense. These actions are executed by the little muscles which move the ossicles of the ear, so as to vary the degree of tension of the membranes of the tympanum, and of the fenestra ovalis. In many of the inferior animals, especially the dog and the horse, this synergy extends to the muscles which move the external ear.

Taste. Sapid impressions on the palate, if agreeable, provoke the secretion of the salivary glands; and in some instances the

mere idea of savoury food in a hungry person, will cause a little jet of saliva into the mouth, from the parotid glands. The action of the muscles of deglutition is also naturally associated with sapid impressions upon the palate.

Organs of Respiration. The lungs and the muscles subservient to respiration are connected by a similar relation; i. e. certain impressions on the lungs instantly excite the action of these muscles, which execute the mechanical motions ministerial to this function. Thus, the absence of pure, or the presence of impure air (carbonic acid) in the lungs, produces an organic sensation in the part, which is immediately followed by contraction of certain muscles, viz. the intercostal and the diaphragm, by means of which the cavity of the thorax is enlarged, and air rushes into the lungs. As soon as the *appetite for respiration* is satisfied, the muscles above mentioned cease to act, and the chest contracts, in consequence of the mechanical disposition and properties of its component parts, expelling part of the air which has now become impure by respiration, and preparing the way for a repetition of the process.

Diaphragm, abdominal muscles, and *glottis,* with certain other organs, viz. *large intestines, uterus,* and *bladder.* These are among the most complicated examples of synergy to be found in the animal system. In the acts of vomiting, defecation, parturition, and evacuation of the urinary bladder, the respective organs are provided with muscular fibres, or with the power of contraction, to enable them to expel their contents. The contraction of these organs, however, is powerfully aided by the action of the diaphragm and abdominal muscles, which in a contracted state exercise a strong pressure upon all the viscera contained in the abdomen, of which they form the anterior, lateral, and superior walls. It is very manifest, therefore, that the contraction of these powerful muscles, exerted immediately upon the hollow organs contained in the abdominal cavity, will materially aid them in getting rid of their contents. Hence, in every one of the actions above mentioned, the assistance of these muscles is called in. It is to be considered, however, that the abdominal muscles and diaphragm are muscles of respiration, and that in this function they act alternately; the diaphragm by its contraction expanding the chest, and thus promoting the entrance of air into the lungs, and the abdominal muscles, if their aid be necessary, contracting *afterwards,* drawing down the ribs, and at the same time pushing up the contents of the abdomen against the now relaxed and yielding diaphragm; and thus, by compressing the lungs, forcing out the air contained in them. The habitual action of these muscles in respiration then is not simultaneous, but alternate, and the effects which they produce as muscles of respiration, are of an opposite kind, i. e. they are antagonizing muscles, the dia-

phragm pressing the viscera downwards, and the abdominal muscles forcing them upwards. Now, for these muscles to compress the abdominal viscera between them, they must be made to act together.

But besides this, it is also obviously necessary, either that their actions be exactly balanced, i. e. that neither contract with greater force than the other, or that the weaker be supported by some means against the superior power of the stronger. If, e. g. the abdominal muscles should exert a more powerful action than the diaphragm, unless the latter can be sustained in its antagonizing action, it must yield to the superior power of the former, and be pushed up into the thorax, at the same time expelling the air from the lungs. In all violent efforts in which the abdominal muscles are called into action this would be found in fact to be the case, i. e. instead of co-operating towards the desired effect, they would expend their force in expelling air from the lungs.

In order to prevent this effect, it is necessary to support the diaphragm, and thus prevent its yielding to the superior action of the abdominal muscles, which is effected by the closure of the glottis. The constrictors of the glottis, therefore, are associated with the diaphragm, in all cases where it is necessary to maintain this muscle in a contracted state, against the powerful contraction of the muscles of the abdomen. By closing the glottis, they prevent the air from passing out of the lungs, without which the diaphragm cannot be forced up into the thorax by the action of the abdominal muscles. In the actions above mentioned then, i. e. in vomiting, defecation, parturition, and the evacuation of the urinary bladder, the ultimate effects are the results of the following combined actions: 1. The organic sensation excited in the hollow organ by the presence of its contents. 2. The muscular contraction of the organ excited by the sensation. 3. The synergic action of the abdominal muscles and the diaphragm. 4. The closure of the glottis, by which the antagonizing muscles just mentioned are enabled to act in concert. 5. The relaxation of the sphincter muscles of the organs to be evacuated, which are antagonists to the forces above mentioned.

The constrictors of the glottis also synergize with the diaphragm, in all those muscular efforts which require the walls of the thorax to be made a fulcrum or point of support for the muscles called upon to act.

The limbs also are connected together in their motions by certain relations. The two arms and hands naturally perform analogous motions, or move in a similar manner. Almost every child knows the difficulty of striking with one hand and rubbing with the other at the same time; but a still more difficult task is to move the two arms round each other in opposite directions.

Sympathy.

I. *Organs of Sense.* 1. The *eye* with the *diaphragm.* A vivid impression of light on the eye sometimes excites sneezing. With the *stomach* and *intestines.* Worms occasion dilatation of the pupil; and morbid states of the stomach may give rise to amaurosis.

2. The *ear* with the *teeth,* &c. Sharp grating sounds set the teeth on edge, and sometimes cause secretion of tears. Irritation in the external meatus may give rise to toothache, to itching in the pharynx, and even to cough.

3. *Sense of smell* with *stomach* and *heart.* Odours sometimes occasion vomiting, and sometimes syncope. Stimulant applications to the nostrils, are among the best means of rousing a person from a state of syncope.

4. The *skin* as an organ of sense is connected by important sympathies with internal parts. 1. *With the diaphragm.* Hence the sensation excited by tickling provokes the involuntary contractions of this muscle, termed laughing. 2. *With the brain.* The same sensation, if excessive, may act upon the brain, and give rise to convulsions. 3. *With mucous membranes.* Cold applied to the skin will stop bleeding from the nose or lungs. Very frequently it produces catarrh, and a variety of other morbid affections.

II. *Brain.* The brain is connected by sympathy with the heart, lungs, and stomach. Hence, morbid affections of it give rise to irregular actions of the heart, as slow, intermitting or irregular pulse; to disordered respiration, or difficult breathing; and to sickness of the stomach.

III. The *diaphragm* with nearly all parts of the inner surface of the alimentary canal. Thus, irritation applied to the fauces excites the action of the diaphragm and abdominal muscles, through the medium of the stomach, giving rise to vomiting. Even after the division of the œsophagus, tickling the uvula will excite vomiting. Certain impressions on the mucous membrane of the stomach, and irritating causes acting upon any other part of the alimentary canal, may lead to the same consequences. Hence vomiting is a common symptom of irritation of the stomach, and of strangulated hernia, colic, and other intestinal affections.

IV. *Abdominal muscles* with the *air passages.* Irritating causes acting upon the latter, frequently provoke sudden contractions of the abdominal muscles. Thus an irritation seated in the tracheo-bronchial mucous membrane, excites these muscles to contract; the consequence of which is, that the air imprisoned in the air vesicles of the lungs, is expelled with a noise, and in its exit, brushes out the mucus or foreign substances which may accidentally be present in the lungs. This is *coughing.*

If the irritating cause exist in the nasal passages, a similar effect is produced; except that the air, after its exit from the lungs, instead of escaping from the mouth, is directed through the nasal fossæ, giving rise to the phenomena of *sneezing*.

V. The *heart*. This organ is more frequently the term than the starting point of sympathy; and in this passive relation, it is connected chiefly with the brain and stomach. The action of the heart is well known to be exceedingly influenced by moral causes, and by certain impressions or morbid states of the stomach. For example, irritation of the stomach from flatulence or other causes, will frequently give rise to an intermitting pulse, or more serious cardiac affections, which will disappear with the discharge of wind, or removal of the causes of irritation. The heart, however, appears to exert an active sympathy in cases of approaching syncope, accompanied with retching or vomiting.

VI. The *stomach* is the starting point, and the term of many normal and pathological sympathies. Several have already been mentioned, and a few more only will be noticed. Inflammatory affections of the brain frequently excite sickness and vomiting. The same symptom often accompanies affections of the kidneys, and pregnancy. Repletion, or oppression of the stomach, may give rise to severe pain in the frontal sinuses, or symptoms of oppressed brain; to difficulty of breathing, or asthma; and irregular pulse, from the sympathy between the stomach, and the brain, the lungs, and the heart, respectively.

VII. The *liver* is connected by sympathy with the *brain*. Wounds of the head sometimes give rise to inflammation and abscess of the liver; and moral causes, especially a fit of passion, sometimes give rise to a copious secretion of bile; of which the following case affords an example. A young officer having received a blow in public, and being forcibly prevented from resenting it, was suddenly affected with a universal jaundice, becoming yellow from head to feet. This was succeeded by fever and delirium, and he died in convulsions.

VIII. *Sexual organs*. The *uterus* and *mammæ* are intimately associated in their functions, and mutually affected by each other. Impressions radiate in both directions from these organs to each other. In the male, there is a striking sympathy between the sexual organs and the larynx, and pilose system, especially about the face. Hence, the sudden developement of the male sexual organs at puberty, causes sympathetically an enlargement of the larynx, indicated by a striking change of voice, and the growth of the beard. The extirpation of the former parts in infancy, prevents the developement of the latter from taking place at puberty.

A curious sympathy is developed by injecting water into the veins, which occasions immediate and rapid motions of deglutition.

Another, which I have long since observed in myself, is that

by pressing with the finger upon the upper lip, I can almost invariably put a stop to the hiccups; in this case I distinctly feel the propagation of the influence downwards toward the region of the stomach.

There is another variety of sympathy, in which certain organs are connected by a kind of reciprocal relation, i. e. when the activity of one is increased, that of the other is diminished, and *vice versâ.* This has been called antithesis, or antagonism. For example, when the stomach is actively engaged in the work of digestion, the brain is torpid. And if the brain be intensely occupied with intellectual labour, the stomach is insensible to the stimulus of hunger. A similar sympathy exists between the brain in the exercise of its intellectual functions, and the external senses; between the skin and the kidneys; the kidneys and the mucous membrane of the lungs, &c.

The sympathies, for the most part, do not admit of explanation in the present state of our knowledge. There is reason to suppose, that in general they require the intervention of the nervous system.

CHAPTER XXXI.

SLEEP.

Sleep is a periodical suspension of the animal functions, during which the individual is deprived of his consciousness, of his sensibility to impressions made upon his organs of sense, and of his power of voluntary muscular action.

The animal functions, viz. those of sense, of voluntary motion, and of the voice, together with all those functions of the brain in which the consciousness or the will are concerned, as perception, judgment, memory, &c. are strikingly distinguished from the other functions, by the remarkable circumstance, that they cannot be kept in uninterrupted action beyond a certain period, of a few hours' duration; after which, a peculiar sensation, termed fatigue or lassitude, irresistibly compels us to suspend their exercise, a torpor or oblivion steals over the senses, wraps them up as in a mantle, from surrounding objects, and, at length, reaching the brain, involves the centre of animal life in unconsciousness, and wholly isolates the individual from the external world.

The approach of sleep is announced by an internal sensation, termed drowsiness, which gradually increases in strength, and, at length becomes irresistible. It is accompanied by frequent yawnings, languor of the muscles, heaviness of the eyes, and inclination to close them, difficulty of supporting an erect or sitting posture, and a strong inclination to lie down. The head inclines towards the chest, or sinks upon one shoulder; the external senses become torpid, and the powers of sensation gradually retreat inwards, to the brain, leaving the organs with which they are connected, insensible to external impressions. The voice and speech are also affected with the same torpor. The voice becomes feeble, the articulation is confused, indistinct, and unintelligible, and at length ceases. The muscles of respiration, and the orbicular muscles of the eyelids, form the only exception to the cessation of voluntary muscular action. Respiration is still carried on, though in perfect sleep, chiefly by the diaphragm; and the orbicular muscles contract at the approach of sleep, to close the eyes against the impression of light.

The functions of the brain, also, are suspended in sleep. A kind of delirium seizes upon the mind, in which objects and images float confusedly through it, which are partly the result of external impressions imperfectly perceived, and exciting an imperfect reaction in the brain. The internal sensations, as hunger, thirst, pain, &c. cease to be felt, and the intellectual and moral operations are suspended; consciousness is for a time abolished, and sleep at length is fully established.

During this suspension of the animal functions, the nutritive, or organic, continue without interruption; and according to some physiologists, even with greater activity than during the waking hours. This, however, is not the fact. Respiration is slower and deeper, and sometimes noisy; the pulsations of the heart and arteries are also less frequent, though the pulse is fuller; the temperature falls—a circumstance which is partly owing to the diminished frequency of respiration; the cutaneous transpiration is increased, and the urine is secreted less abundantly in the same proportion; the urine also becomes more concentrated, and loaded with saline matter from the absorption of its aqueous parts. Hence, the formation of calculus of the bladder is apparently promoted by habits of great indulgence in sleep.

The duration of sleep varies with numerous circumstances, from a few minutes to several hours. The average duration of the regular periodical sleep, in adults, is from five to eight hours. Infants require much more. The quantity of sleep required by different persons depends much on the power of habit. Men engaged in active and anxious pursuits, requiring all the time they can possibly afford, frequently acquire the habit of sleeping very little. Blane states, that he was informed by the celebrated

General Pichegru that, in the course of his active campaigns, he had, for a whole year, not more than one hour of sleep, on an average, in twenty-four hours.* The same writer mentions another curious fact on this subject, which he learned from a gentleman who had long resided in China. The missionaries in that country, wishing to devote as much of their time as possible to their duties, used the following means to abridge the period of their sleep. They threw themselves on a couch, with a brass ball in the hand, under which was a brass basin. The moment they dropped asleep the ball fell from their hand into the basin, and the sound waked them. This momentary sleep, they found, afforded all the refreshment which nature required. Alexander the Great, it appears from Q. Curtius, sometimes adopted a similar method to reduce the period of his sleep to the smallest possible allowance. The explanation of the fact, that in many cases so little sleep is sufficient to afford the necessary refreshment, is to be found in the circumstance that the first part of sleep is the most restorative. After sleep has continued a sufficient time, and is approaching to its close, some of the animal functions begin to act again, or at least are disposed to do so, on the application of the slightest excitation. Indeed, in sleep, the animal functions are not all plunged in the same degree of torpor, or at least they do not all require the same quantity of repose to recover their aptitude to act. Those which require the least, and which, of course, are most easily excitable, are the intellectual faculties, as appears by the frequency of dreams, which may be excited during sleep by any irritation, external or internal. Next to the mental faculties, the senses of touch and hearing are most excitable, as appears from the changes of posture which so frequently take place during sleep, and which are probably owing to some uncomfortable sensation, produced by impressions on the surface of the body, and from the fact that a loud noise frequently rouses a person from sleep. The sense of sight, and the voluntary muscular actions, are those which are roused from sleep with the greatest difficulty.†

The remote *causes* of sleep are various, but they may all be reduced to the following heads, viz:

1. The exhaustion occasioned by the impressions constantly made upon the senses by external objects, and the reaction of the cerebral and voluntary powers produced by these impressions; or in the language of some of the German physiologists, fatigue and exhaustion, produced by the conflict between the macrocosm and the microcosm.

2. The diminution or abstraction of the excitations habitually applied to the system, by which the animal functions are main-

* Elements of Med. Logic. † Dict. de Medecine.

tained in a state of activity. Hence, darkness, silence, solitude, cold, loss of blood or of other fluids, promote sleep, and, for a similar reason, the gratification of animal desires frequently produces a disposition to sleep.

3. Increased activity of other organs, or a concentration of vitality in them, producing a derivation of vital power from the same.

4. A defect of intellectual excitation, unless compensated by exercise, or external incitements. Hence, people without occupation, and of few ideas, generally sleep a good deal.

5. Certain pathological states of the brain, causing a diminished nervous energy, constitute another class of causes; as, for example, mechanical compression, or congestion of the brain, the use of narcotics, particularly opium, &c., alcohol, &c.

To the first class belong protracted watchfulness, long-continued bodily or mental exertion, especially the latter; because the operations of the intellect and of the senses are the highest manifestations of life; violent pain, and exhaustion from any cause.

To the second, the abstraction of light and sound, and certain uniform monotonous impressions made upon the organs of sight and hearing, as the murmuring of the winds, the buzzing of bees, the noise of a distant waterfall, the ticking of a watch, the dull monotony of a prosing speaker, and the sudden cessation of such sounds.

To the third class belongs *digestion*, which is frequently accompanied with sleepiness, because the powers of the system are then concentrated in the stomach. The somnolency which frequently accompanies fevers, inflammations, &c. and some other diseases, may be referred to the same head, and the greater proportion of sleep required by children, and by females during utero-gestation; since in these cases, production and nutrition are maintained in a state of great activity, at the expense of the higher manifestations of life.

The fourth class needs no illustration.

The efficient cause of sleep is unknown. Blumenbach supposes it to be a diminished flow of arterial blood to the brain, since this fluid is the great excitant of the brain, and is necessary to maintain the reaction of this organ upon the senses and the voluntary muscles. The influx of blood is diminished by its derivation from the brain, and its congestion in other parts; and it is impeded by pressure upon the brain, occasioned by foreign substances, as serous or purulent effusion, or depression of a piece of the cranium. It is not very clear, however, in what mode the exercise of the sensorial and voluntary powers, the usual causes of sleep, can induce a diminution of the quantity of arterial blood in the brain. Indeed, causes which increase, as well as those

which diminish the quantity of blood in the brain, may induce sleep. Hemorrhage may bring on sleep, perhaps by depriving the brain of the necessary quantity of blood; but the same effect may also be produced by obstructing the return of blood from the brain, or by increasing the influx of blood into the organ, as by the use of strong drinks, which occasion a fulness of its vessels.

Haller and several other physiologists have supposed that sleep depends on an accumulation of blood or other fluids in the vessels of the head, causing pressure upon the brain, and impeding its functions; an opinion deduced partly from the effects which pressure upon the brain, from congestion of blood or other causes, actually produces. It does not appear, however, in what manner the usual causes of sleep can produce an accumulation of blood in the brain; and besides, we ought not to confound natural, healthy sleep, with a pathological phenomenon produced by a morbid state of the brain.

Berthold regards sleep as a periodical interruption of the higher vital manifestations, characterized by the descending to a lower degree in the scale of organic life; so that in sleep, an animal of a higher order resembles one of a lower, and the lower are brought to the condition of plants. The degree and the quantity of sleep, he supposes to be in the direct ratio to the developement of the organization, and to be measured by the interval which separates the highest from the lowest manifestations of life. Hence, according to Berthold, the inferior orders of the animal world, in which this interval is small, sleep but little, and plants, perhaps, scarcely at all. Worms and insects, for example, sleep very little; the amphibia and fishes, which are higher in the scale of organization, probably sleep more, but still, according to Berthold, comparatively little; but as we ascend higher in the scale of animal life, sleep becomes a more conspicuous and important phenomenon.

Tiedemann remarks, that, from the very constitution of the nervous system, the organs of sense and the muscles of voluntary motion, and, to a certain degree, the brain itself, are so affected by the excitations to which they are subject, and by their own proper actions, as to lose their receptivity to these excitations, and to be rendered incapable of continuing the exercise of their functions. During sleep, the constitution of the nervous system is restored to the necessary conditions by the powers of nutrition; whence its organs again become capable of acting under the influence of the agents which are adapted to excite them.

Sleep is periodical, returning at stated times, and, in most animals, once in twenty-four hours; most animals, and man among the number, sleep in the night. The absence of the stimulus of solar light, the diminished warmth, the comparative

stillness of night, the exhaustion of the animal powers by the labours of the day, all contribute to render the night a suitable time for sleep. Some animals, however, sleep most in the day, and are awake during the night, as the cat, the fox, the otter, &c.

Certain animals sleep several months during the winter, and some during the summer months. Among the mammiferous animals, the bear, the badger, the hedge-hog, the marmot, the bat, &c. are hybernating animals. Some among the feathered tribe, and many of the amphibia, also, become torpid during the winter months; and the same is true of some of the invertebrated animals. According to Humboldt, the *Erinaceus caudatus* sleeps three months in summer. In this state of torpor the temperature of the animals falls very much, their secretions are disminished, their excretions suppressed, their respiration very slow and scarcely perceptible, their circulation very much diminished, and sensibility to external irritations suspended. Hematosis is imperfect, and hence their arterial blood differs less from venous blood than in their waking intervals. A remarkable circumstance is, that the liver, in hybernating animals, becomes enlarged during their winter's sleep.

Very frequently sleep is imperfect, and, instead of involving all the animal functions, seizes upon some of them only, leaving the others in a state of greater or less activity, and permitting a partial intercourse with the external world.

There are several varieties of imperfect sleep. In some instances, certain sensations are felt; as, for example, when a person asleep changes his posture, or draws the bed-clothes over him, or, as frequently happens with infants, kicks them off. The same facts prove that voluntary muscular power may be excited in sleep, and consequently that intellectual determinations may still be formed. Besides, persons sometimes sleep in such postures as require an exercise of some of the voluntary muscles; as, for example, when a person falls asleep sitting in a chair, or on horseback, or even, as sometimes happens, when standing up.

In some cases the motions of a sleeping person correspond with dreams which are present in his mind, as when infants move their lips as in sucking, or laugh aloud, or sob in their sleep. In like manner, other animals frequently give expression to their dreams by corresponding actions. Thus dogs sometimes utter a whining noise or low short barking in their sleep. I have known a puppy that while sleeping on the carpet, would immediately bark out in his sleep if a certain key of the piano* were struck, but give no heed to any other.

* E flat.

Dreams.

Very frequently some of the intellectual operations are carried on during sleep, constituting the phenomena of dreams. All the faculties of the understanding, the perception, memory, imagination, invention, reasoning, judgment, &c. may be the subjects of this phenomenon. In the fanciful but beautiful language of Bichat, dreams are a portion of animal life, escaping from the torpor in which the rest of it lies buried.

Dreams are excited by various causes; sometimes by the state of the brain, this organ not being completely asleep, and continuing to exercise some of the functions which are usually suspended in sleep; sometimes by sensations, powerful enough to be felt, but not enough so to wake the subject from sleep; as, for example, a loud sound, an uncomfortable posture, the stimulus of urine distending the bladder, thirst, hunger, pain, an overloaded stomach, &c.

There are many varieties of dreams.

1. One class consists of images and ideas excited by sensible impressions, and frequently display, with a great talent for exaggeration, a remarkable readiness and ingenuity in the slumbering brain, in accommodating its fictions to the nature of the impressions which excite it. Des Cartes was bitten by a flea, and dreamed that he was stabbed by a sword. Galen dreamed that he had a stone leg, and found on waking that his leg was struck with palsy. A person falling asleep with an oppression of the stomach, has dreamed that he had an anvil lying on him; and Dr. Reid relates, that on a certain occasion the dressing upon his head, which had been blistered, having got displaced in his sleep, he dreamed that he had fallen into the hands of savages, who were stripping him of his scalp. In this class may be included those cases in which dreams are excited by words whispered in the ears of a sleeping person. In such cases the dreamer may sometimes be led into a conversation by a person awake, if the latter speaks in a low or gentle tone. A loud voice, instead of conveying any meaning to the sleeper's mind, is more apt to wake, and perhaps in a fright. Reil relates a curious example of two dreamers getting into conversation with each other.

2. Another class of dreams consists in the revival of former ideas or of scenes which have long since passed away, without the least consciousness in the dreamer's mind of the intervening time.

Persons long since dead sometimes appear to us in our dreams, and we imagine ourselves to be in conversation with them precisely as if they were still living. Yet in these cases there is sometimes a sentiment of profound melancholy on the mind of

the sleeper, as if there was a secret consciousness that his dream is a delusion, and that the object of his dreams, with whom he seems to be engaged in actual discourse, has long since been separated from him for ever. Such dreams are apt to be followed the day after, by an unusual weight upon the spirits, for which the subject is at a loss to account, unless he happens to think of his dream, when the mystery is at once explained. To this class belong those dreams in which events or circumstances which had been entirely forgotten, or even perhaps unnoticed at the time of their occurrence, are revived, or for the first time brought distinctly before the mind. Dr. Abercrombie seems to think that the knowledge of languages, which have been once learned, but afterwards forgotten, is sometimes revived in dreaming, as it is well known to have been in several instances in the delirium of fever. Of this fact he mentions an example which occurred in one of his friends, who in his youth was very fond of the Greek language, and had made considerable progress in the study of it, but having engaged in other pursuits had afterwards so entirely forgotten it, that he could not even read the words of the language. Yet he often dreamed of reading Greek books, and with a strong impression of fully understanding them.

A still more remarkable instance is that of Dr. Blacklock, who lost his sight when an infant of a few months old, and, it is said, had an impression in his dreams of a sense which he did not possess when awake. He described the impression by saying that, when awake, there were three ways by which he could distinguish persons, viz. by hearing them speak, by feeling their head and shoulders, and by attending to the sound and manner of their breathing. In his dreams his impression of objects was of a different kind. He imagined that he was united to them by a kind of distant contact, effected by means of threads or fine strings passing from their bodies to his own.

This class of dreams is curiously contrasted with the first in one respect, viz. in relation to the perception of time. In the first class a moment of time is sometimes drawn out to a very considerable duration; in the other a long interval of time seems to be annihilated. In a person suddenly waked from sleep by a loud noise, the imagination in the moment of transition from sleep to consciousness, will find time enough to conjure up an extended scene dressed out with many appropriate circumstances, and all ingeniously adapted to the character of the impression. Of this the following is a curious instance. A gentleman after sleeping in a damp place, was for a long time afterwards unable to sleep in a recumbent posture, without being liable to a feeling of suffocation. Whenever this occurred, he dreamed that a skeleton grasped him violently by the throat. He could sleep in

a sitting posture without any uneasiness; and in order to prevent the occurrence of the dream, he procured a person to watch by him, with orders to awake him whenever he began to sink down into a lying position. Notwithstanding this precaution, he was on one occasion attacked by the skeleton, and a long and desperate struggle ensued before he awoke. Upon chiding his attendant for his remissness in not waking him sooner, he was assured that he had not lain an instant, but had been awakened the moment he began to sink.

In the second class of dreams, consisting in the seeming revival of former scenes or occurrences, there is no perception of the intervening time, which to the dreamer's mind is absolutely annihilated. For the dream does not merely carry him back to the former scene, but it strangely mixes up long past and recent occurrences in such a manner as to imply that there is no perception of any distinction of time between them.

3. Recent occurrences or impressions, especially such as are deeply interesting to us, frequently recur in our dreams. We fall asleep with the impression on our minds; and the moment the senses are sealed up and the reins of thought drop from the relaxing grasp of slumbering reason, the imagination, under the influence of the feeling, catches them up, and hurries us through scenes in which the impression is embodied in a thousand strange or fantastic shapes.

In some cases the imagination is less active, and our dreams seem rather to be gotten up by memory, who generally appears, however, in masquerade, reviving the scenes or occupations in which we have recently been engaged. The Latin poet Claudian has described with great elegance this class of dreams in the following verses:

> "Omnia quæ sensu volvuntur vota diurno,
> Tempore nocturno reddit amica quies.
> Venator defessa thoro dum membra reponit;
> Mens tamen ad sylvas, et sua lustra redit.
> Judicibus lites, aurigæ somnia currus,
> Vanaque nocturnis meta cavetur equis.
> Gaudet amans furto, permutat navita merces,
> Et vigil elapsus quærit avarus opes.
> Me quoque musarum studium sub nocte silenti
> Artibus innumeris sollicitare solet."

Every one's experience will furnish him with abundant examples of this kind of dreams.

4. There are some dreams in which, as Abercrombie remarks, some strong propensity of character is embodied; and by some natural coincidence, the scene which it suggests to the imagina-

tion is afterwards realized. Mr. Combe mentions the case of a man who dreamed of committing murder, and some years afterwards actually perpetrated the crime.

5. There are others in which some strong emotion is excited during sleep; or some moderate one, which had been present before sleep, is much exaggerated in this state, and embodies itself in an imaginary scene, which in several instances has been realized afterwards in a very extraordinary manner. The following is an instance related by Abercrombie as undoubtedly authentic. A clergyman who had arrived at Edinburgh from the country, and was sleeping at an inn, dreamed of seeing a fire, and one of his children in the midst of it. The dream awoke him, and he instantly left town to return home. When he came in sight of his house he found it on fire, and one of his children in a state of extreme peril, whom he succeeded, however, in rescuing from the flames. Another case of a similar kind, related by the same author, was that of a gentleman of Edinburgh affected with popliteal aneurism, and on whom the operation for this disease was appointed to be performed on a certain day. Two days before the appointed time, the patient's wife dreamed that a change had taken place in the disease, which would render the operation unnecessary. Upon examining the tumour the morning after, the gentleman was astonished to find that the pulsation had entirely ceased. It never afterwards returned, and the gentleman experienced the very rare good fortune of a spontaneous cure of aneurism. Most of these extraordinary coincidences, and there are many such, may be accounted for on natural and simple principles; but Abercrombie himself remarks, that there are some which do not admit of an explanation on any known principles, and that we are compelled to receive them as facts, which we can in no degree account for.

6. There is another class of dreams in which the reasoning and inventive powers are the principal actors, and are employed and perhaps successfully, in the investigation of difficult questions which had baffled their powers in the waking state. Of these dreams there are several examples on record, and the experience of many individuals will probably furnish them with others. The most remarkable circumstance connected with them is, that the intellectual processes of which they consist go on spontaneously and without effort; they are carried on simply by the laws of association, without any intervention of the will, and yet they lead to results which the same powers of reason, acting under the highest excitation from volition, had been unable to reach. In these cases, the previous lucubrations of the dreamer had undoubtedly furnished his mind with all the data or materials necessary for the solution of the question, in which he was engaged, and all that was necessary was, that these data should

be arranged in a certain order, to enable him to discover the connexion running through the whole. It is not difficult to conceive that in a mind exhausted by intellectual labour, the strong exertions of the will might obscure the perception of the true relations of these materials to one another; and that, on falling asleep, the voluntary efforts no longer agitating the mingled mass of thought, the floating and disunited elements might gradually settle down, and by a sort of intellectual affinity naturally fall, each into its proper place; the long sought for truth thus crystallizing, as it were, from the turbid solution of thought.

The successful result in these cases, therefore, is rightly due to the previous voluntary labours of reason made during the waking hours.

A remarkable circumstance respecting dreams is, that we mistake our ideas for actual perceptions, and suppose that the trains of images which pass through our minds represent scenes which actually exist. This is probably owing to the circumstance, that, during sleep, the senses are incapable of admitting external impressions; and that, of course, we do not receive sensible impressions, with which we may compare the ideas which arise in our minds, and learn the difference between the two. Such a comparison is constantly, though unconsciously, made during our waking hours; and hence there is no danger of confounding the images which arise in our minds, with actual impressions on the senses. But in sleep we have no such means of correcting the illusion; and as the ideas and images, which pass through our minds in sleep, constitute at this time our highest, and indeed our only consciousness; and as experience has uniformly associated the exercise of consciousness, in our waking hours, with the presence of external objects, it seems unavoidable, that, in such circumstances, we should give credence to our ideas, as representations of objects really existing.

The train of ideas in the mind, during sleep, except so far as it may be disturbed by sensations accidentally excited, which may direct the current into different channels, is regulated by spontaneous associations, in which volition and the judgment, which are now dormant, have no share; and hence, the absurd and inconsistent ideas, of which our dreams are generally composed.

Scmnambulism.

In some cases of imperfect sleep, the muscles of locomotion and those of the voice, retain their power of action, while the external senses remain buried in repose. This state constitutes that curious affection termed *somnambulism*, which may be regarded as a greater degree of dreaming.

The phenomena of somnambulism may be reduced under the following heads. 1. Suspension, more or less complete, of the external senses, and a state of isolation from the external world, and, in some instances, extraordinary increase of power of vision and external feeling. 2. A concentration and increase of energy of the powers of the mind, owing perhaps to their not being distracted by impressions upon the senses, but exclusively occupied with their own peculiar actions. 3. The power, in some cases, of communicating with a somnambulist, who can neither see nor hear, by touching some part of his body, and thus enabling him to understand and converse with you. 4. To these may be added, that sleep-walkers generally have no recollection whatever, after they awake, of what they had done and said while asleep.

1. Somnambulists, like persons in ordinary sleep, are not sensible to external impressions. Sometimes their eyes are wide open, yet are so insensible to light, that the strong light of a lamp may be thrown directly upon them without producing the slightest indication of their perceiving it. The sense of hearing, also, is frequently entirely suspended. Sleep-walkers are sometimes so deaf, as to be apparently insensible to the loudest sounds, excited close to their ears. The sense of smell, also, is sometimes so entirely suspended, that the most pungent odours, as that of strong hartshorn, held directly under the nose, apparently do not excite the least sensation.

One of the senses, however, viz. that of touch, appears to be in a state of extraordinary activity and acuteness.

Sometimes the external senses are not suspended, but are in a very peculiar state. A sleep-walker once rose from his bed with his eyes shut, lighted a lamp, and began to write by it. A person who happened to see him, purposely extinguished his light; and though there were others burning in his chamber, he did not appear to see by them, but seemed to be plunged in profound darkness, and went and lighted his lamp again.* Persons engaged in literary occupations have been known to get up in their sleep, go to their writing-desk, and begin their usual business of writing, and even to continue it, after an opaque substance had been purposely interposed between their eyes and the paper they were writing upon. There is a story of a young ecclesiastic, who would sometimes get up in his sleep, write his sermons, and correct them with the greatest care; compose music, and write it off carefully, and recopy it if he thought it incorrect, and review it with the greatest attention—and all this with his eyes shut, and even with a sheet of paper held between his eyes and the paper on which he was writing.

* Dict. de Medecine.

These facts were deemed incredible by some, until the extraordinary narration of Jane Rider fully established the fact, that a somnambulist may enjoy perfect vision with the eyes closed, and even covered with a thick bandage. In one experiment, the author of the narative informs us that he took two large wads of cotton, and placed them directly on the closed eyelids, and then bound them on with a black silk handkerchief. The cotton filled the cavity under the eyebrows, and reached down to the middle of the cheek, and various experiments were tried to ascertain whether she could see. In one of them, a watch inclosed in a case was handed to her, and she was requested to tell what o'clock it was by it; upon which, after examining both sides of the watch, she opened the case, and then answered the question. She also read, without hesitation, the name of a gentleman, written in characters so fine, that no one else could distinguish it at the usual distance from the eye. In another paroxysm, the lights were removed from her room, and the windows so secured that no object was discernible, and two books were presented to her, when she immediately told the titles of both, though one of them was a book which she had never before seen. In other experiments, while the room was so darkened that it was impossible, with the ordinary powers of vision, to distinguish the colours of the carpet, and her eyes were also bandaged, she pointed out the different colours in the hearth-rug, took up and read several cards lying on the table, threaded a needle, and performed several other things, which could not have been done without the aid of vision.

It is also remarkable, that somnambulists will go about in the dark with their eyes closed; with the utmost security avoid obstacles in their way; open windows and get out of them; climb up on the roofs of houses; and apparently take pains to get into situations of great peril, from which they extricate themselves with extraordinary adroitness and skill. A gentleman once informed the author, that he awoke one night, and to his astonishment, found himself swimming in the midst of a pond. It is impossible to doubt that in such cases they enjoy the power of vision. It is stated in the narrative of Jane Rider, that night after night she was seen to perform things which it seemed impossible for her to do without the aid of vision. Her friends were convinced that she saw when her eyes were closed and in the dark. When obstacles were placed in her way, or the position of a thing was changed, she always observed it, and accommodated herself to the change.

Sometimes, instead of being deaf, sleep-walkers appear to hear sounds, and are easily awaked by them; and what is very remarkable, they sometimes hear and understand what is said to them, answer questions, and even carry on connected con-

versation, without waking up. Jane Rider, in her paroxysms, we are told, heard, felt, and saw, but the impressions on her senses had no tendency to waken her.

2. While the external senses are in this singular state, the faculties of the mind in some instances acquire an extraordinary degree of energy and power; and a sleep-walker sometimes will perform things which he could not possibly do when awake. Somnambulists have sometimes composed poetry, performed mathematical calculations, and discoursed in a style much beyond their ability in a waking state. These facts seem to prove, that during somnambulism, the external senses being closed as it were to the external impressions which excite them during the waking hours, there is a concentration of power in the faculties of the mind, which acquire an unusual degree of energy and activity.

3. Another very curious and remarkable fact which has sometimes been observed is, that a somnambulist, though in a profound sleep, and deaf to very loud noises, can yet be made to hear and to understand another person, and reply to his questions, if the latter places his hand upon the pit of the sleeper's stomach, or perhaps merely touch any part of his body; and yet will remain wholly insensible to the voices of others around him, and speaking at the same time.* A fact of this kind is related by Dupau, in his "Lettres sur le Magnetisme," and others have been mentioned to the author.

4. Somnambulists, when they awake, have no recollection of what they had said or done while asleep. Not the slightest impression of what had occurred during the paroxysm, seems to remain on the mind after they awake. In some rare cases, somnambulists have appeared to possess a double consciousness and memory, i. e. in the paroxysms to retain the knowledge which they possessed in previous paroxysms, but to forget every thing they knew in the intervals; and in the intervals, to remember all they had known in previous intervals, but to forget every thing they knew in the paroxysms. Somnambulism appears to partake of the nature of certain cerebral diseases, as ecstasies, catalepsy, and epilepsy. Prichard considers it as a morbid modification of ordinary dreaming.†

* Dict. de Medecine, Magnetism Animal. † Diseases of the Nervous System.

CHAPTER XXXII.

ANIMAL MAGNETISM.

In this chapter I shall give a brief account of some of the alleged facts in relation to the subject of animal magnetism, without expressing any opinion respecting the truth of these extraordinary statements. I am induced to insert a short notice of this subject, from the fact that it has attracted a considerable degree of interest of late years, in some parts of Europe, and that several distinguished men have enrolled their names among its disciples. For the following account, I am indebted chiefly to the article on animal magnetism in the Dictionnaire de Médécine, by Rostan, and to Georget's Physiologie du Système Nerveux.

The expression, animal magnetism, is used in different senses, either to signify a peculiar state of the nervous system, giving rise to a series of phenomena of a very extraordinary kind, and produced by a certain influence, exerted by another individual upon the person who exhibits them; or, secondly, to denote the processes which are employed to produce these effects.

We are told, that as two individuals are necessary in performing these processes, certain conditions in the two are necessary for the success of the experiment. On the part of the person who is to be the subject of the magnetic influence, is required a nervous temperament, and a feeble and excitable constitution. Females subject to epilepsy, catalepsy, or other nervous disorders, are well adapted to the manifestations of the magnetic influence. In most instances, it is also necessary that the subject feel a willingness to submit to the experiment, and a disposition to yield to the influence of this extraordinary agent. This condition, however, is not indispensable, though it is extremely favourable to the success of the experiment. Persons have been thrown into a state of magnetic somnambulism without their knowledge of the means employed; and others, in spite of a strong repugnance to the experiment, and their earnest entreaties that the magnetizer would desist.

On the part of the magnetizer, or the person who exerts this influence, are required also certain conditions. One of these is, a strong and energetic exertion of the will, a vivid desire to produce the effects in question, and a full conviction that he shall succeed in his attempts. The necessity of these moral dispositions in the two parties has given rise to no little ridicule in the opposers of animal magnetism, who forget that the magnetic action is owing to a peculiar state of the nervous system, and that

the moral dispositions required in the parties are themselves only certain states of the nervous system.

When these conditions exist in the two parties, the magnetic influence may be exerted by different processes. The following method may serve as a specimen. The operator places the other party on a seat before him, so that the knees and the ends of the feet may touch, and then grasps the thumbs of the other party with his two hands, and holds them until the temperature of both is the same. He then places his hands upon the two shoulders of the other party, and after a few moments, moves them down the arms, taking care to follow, with the ends of his fingers, the course of the principal nerves, as they pass down the arms. This is to be done several times. The hands are afterwards to be applied to the pit of the stomach, and to remain there until the heat between the two parts become equalized; then to be carried down the trunk of the body to the lower limbs.

These movements are to be repeated several times, after which some of the magnetic phenomena usually begin to manifest themselves. The patient begins to experience a feeling of heaviness and confusion in his head, yawns, stretches his limbs, becomes drowsy, drops his upper eyelids, and at last falls into a deep sleep.

After a few trials, we are told, it is not necessary for the magnetizer to apply the hands at all to the other party. It is sufficient to order him to go to sleep, and he will immediately obey, without the power of resisting the commands of the magnetizer. Some apology may seem necessary for inserting such absurd and improbable stories. But however incredible they may seem, they are gravely asserted by such men as Rostan and Georget. The former of these declares, that in some instances, he merely exerted a strong effort of the will, without even speaking to the subject of the operation, when the latter began to yawn and stretch, and to manifest some of the other signs which precede sleep, and cried out, "What are you doing to me? I beg of you not to make me go to sleep; I do not wish to go to sleep." And Georget asserts, that he had several times been witness to an exertion of the magnetic influence, by the mere energy of the brain, or of the will of the magnetizer, and even at a distance of several feet, and in cases where the two parties were separated by a door or a partition, and the patient had no suspicion of what was going on.

Such are the methods by which magnetic sleep may be induced. The phenomena which this singular state exhibits are extremely curious, and well worthy of physiological investigation. In many respects, they resemble those of common somnambulism; in others, they present some striking peculiarities.

In magnetic sleep the subject seems to be shut out, as it were, from the external world, and to live only in himself. The senses,

especially those of sight and hearing, are entirely suspended. The magnetized sleeper does not appear to hear the loudest noises, nor to see the brightest light. Even the report of a pistol fired close to his ear, occasions no starting, nor any other motion, nor does it prevent his carrying on a conversation already commenced, in an unaltered tone of voice. But a remarkable circumstance, in which magnetic sleep resembles common somnambulism is, that if the magnetizer touch the body of the sleeper with his hand, the latter immediately acquires the power of hearing and understanding the magnetizer, though he remains incapable of hearing any other person.

The eyes, also, in most cases of magnetic sleep, are wholly insensible to light. In some cases the flame of a lamp has been brought so near the eyes of the *sleeper* as to scorch his eyelids, without his manifesting the least sign of sensation. The eyelids are closed and applied firmly and almost convulsively to the eye, so as not to be raised without some difficulty. But if the eye be forcibly opened, the eyeball is found to be rolled up and fixed by a spasmodic action of the muscles of the eyeball, so that only the white of the eye can be seen. When the pupil is visible, it is observed to be dilated. Even when the eye is opened it sometimes remains wholly insensible to light. In other cases the flame of a lamp has produced the impression of a faint whitish light.

The sense of touch is in a very extraordinary state. Sometimes it acquires an astonishing degree of acuteness, so as to become capable of receiving impressions, and of communicating ideas to the mind, which are entirely foreign to its ordinary functions. A person in a magnetic sleep, incapable of seeing or hearing, will distinguish in a moment between different individuals who touch him, if it is merely with the end of a finger. Sometimes these sleepers are aware of the presence of persons, who enter the apartment after they have ceased to see or to hear, who carefully avoid making the slightest noise, and who do not even touch them. Though incapable of seeing or hearing, they are, by some means or other, aware of the objects and of the individuals around them; perhaps in the same manner as the deaf and blind child at Hartford. They avoid, with the greatest care, obstacles lying in their way, which, however, is no more than is frequently done by common sleep-walkers. A most extraordinary experiment, made by a French physician, and related by himself, if it does not wholly exceed the bounds of credibility, will afford a striking illustration of the state of the senses in this strange affection. The experiment is the following, which the writer says he had frequently performed. He took his watch, and placed it three or four inches *behind* the head of a person in a magnetic sleep. He then asked her if she saw any thing. "Certainly," said she, "I see something which shines—it hurts

me." Her countenance at the same time became expressive of pain. He then said to her, that if she saw some shining object, she could immediately tell what it was. She expressed great reluctance to tell; but upon being urged by the experimenter, and complaining of the exertion fatiguing her, after a moment of deep attention, she said, "It is a watch." She was then requested to tell what o'clock it was by the watch; her reply was, "Oh no, it is too hard;" but, upon being again urged to say, she reluctantly consented, and after an effort of great attention, she said, "It wants ten minutes of eight o'clock;" which was exactly true. Astonished at this result, another gentleman who was present, M. Ferrus, after repeating the experiment himself, with the same success, proposed that they should alter the position of the hands of the watch. This was accordingly done several times, and the watch each time placed as before, a few inches behind the head, and, in every instance, the subject of the experiment mentioned the time indicated by the watch with perfect accuracy. In one instance, when the watch was placed *before* her, she mistook the position of the minute hand, though not its distance from the twelve o'clock mark, saying it wanted so many minutes of the hour, when in fact it was just so many minutes after, and *vice versâ*. "Here then," says Rostan, "we see the power of vision transferred from the eye to other organs, which exercise no such function in the natural state." In order to diminish the extreme improbability of such a supposition, Rostan remarks, that plants are undoubtedly sensible to light, without having any organ of vision or even any nervous system; and that probably many of the inferior classes of animals, though destitute of eyes, are sensible to light by the whole surface of their bodies. Worms, for example, retreat into their holes at the light of a lamp. The sensibility which, in man and the inferior animals, is divided into five different species, and distributed among five distinct organs of sense, he supposes to exist in the lowest animals, in all its modifications, in every part of the skin. If this be admitted in regard to the lowest orders of the animal world, where, he asks, is the extreme improbability in the supposition, that when the proper organs of sight in the human species are deprived of the faculty of vision, the power, under some circumstances, may be transferred to another organ of sense, which we have reason to believe possesses and exercises it in some other animals? Why cannot we suppose that the nerves, expanded over the skin, and which are the seat of common feeling and touch, may become endued temporarily with the peculiar modes of sensibility which exists in the nerves of seeing, hearing, smelling, &c.? This view corresponds with that of Berthold, who says, that in magnetic sleep the senses lose their individuality and their peculiar distinctive characters, and become fused, as

it were, with the functions of the nervous system of vegetative life; and in the same degree as the senses lose their distinctive powers and become *indifferent,* the power of common sensation is exalted, and endued occasionally with the senses of seeing, hearing, &c.* This hypothesis must go for what it is worth. It is proper, however, to state here, that the sensibility of the skin in magnetic sleep is very great, and the patient is unable to bear the least degree of cold.

Such are some of the principal facts relating to the state of the senses and of sensation. But we are told, that the condition of the powers of sensation may be influenced anew by an additional application of magnetic power. The senses may be completely paralyzed, and rendered wholly insensible to external impressions, so that the subject of the experiment may be incapable of hearing even the magnetizer himself; the sense of smell so completely suspended that the strongest hartshorn may be applied to the nose, and kept there for several minutes, without exciting sneezing, or any appearance of uneasiness, or in the slightest degree affecting the breathing. The skin also may become so insensible, that pinching it black and blue, or running sharp instruments into it, will excite no feeling; and it is not affected by the application of hot water, or even that of fire. This second application of magnetism may be made without the knowledge, or even suspicion of the patient. The extreme insensibility induced by animal magnetism, is illustrated in a most striking manner by the following extraordinary case, related in a report made on the subject of animal magnetism, by a committee of the medical section of the French Royal Academy of Sciences, laid before this body in June, 1831.

A lady, aged sixty-four, had a cancer of the breast, for which she was magnetized, with no other effect than that of throwing her into a profound sleep, in which all sensibility appeared to be annihilated, while her intellectual operations were carried on with their usual activity. It occurred to the lady's medical adviser, M. Chapelain, to perform the operation of cutting out the cancer, while she was plunged into this profound sleep; and he accordingly proposed the idea to M. Jules Cloquet, the surgeon. The latter deeming the operation indispensable, consented. As a preliminary step the lady was magnetized several times the two evenings previous to the operation; and in this state was prevailed upon to submit to it; although, when awake, she rejected the idea with horror.

On the day fixed for the operation, Cloquet arrived at half past ten o'clook, A. M. and found the patient seated in an elbow chair, in the attitude of a person enjoying a quiet natural sleep. She

* Berthold, Lehrbuch der Physiologie. Lenhossek gives a similar explanation.

had been magnetized by her physician, and thrown into a state of magnetic sleep, and was conversing with great calmness on the subject of the operation she was about to undergo. Every thing being arranged for the operation, she adjusted her dress, and sat down on a chair. Being properly supported by her physician, the first incision was commenced at the arm-pit, and was continued beyond the tumour. The second commenced at the same point, and was continued until it met the first; the enlarged ganglions were dissected out with caution, on account of the vicinity of the axillary artery, and the tumour was extirpated. The duration of the operation was ten or twelve minutes.

During all this time, the patient continued to converse quietly with the operator, and did not exhibit the least sign of sensibility. There was no motion of the limbs or of the features, no change in the respiration nor voice, and no alteration in the pulse. There was no occasion of confining the patient, but only of supporting her. The wound was dressed and the patient put in bed, while still in a state of magnetic sleep, in which she was left forty-eight hours. The wound was then dressed again, and the patient still exhibited no indication of pain or sensibility. Two days after the operation, the lady was awaked out of her magnetic sleep by the physician, and she appeared to have no knowledge nor suspicion of what had occurred.

The muscles of voluntary motion are also subject to the magnetic influence. We are told that any of the limbs or muscles of the patient may be rendered completely paralytic, by the will of the magnetizer; an effect which, however incredible, Rostan declares is most easily and most frequently produced, and which, indeed, he says, *scarcely ever fails!* You have only, says Rostan, to will that a certain limb of a patient shall not move, and two or three gestures are sufficient to throw it into a state of complete paralysis, in which the patient will find it absolutely impossible to move it in the slightest degree; and before he can recover the power of moving it, it must be *deparalyzed* by the magnetizer. Indeed, this astonishing effect may be produced mentally; that is, by a mere exertion of the will, without any accompanying gestures, so that the patient can have no suspicion of the intention of the magnetizer. Rostan says, that he has frequently, in the presence of witnesses, paralyzed any limb that he was requested to affect in this mode, by *a mere effort of his will!* A bystander has been put in communication with the patient, so as to converse with him, and on being desired by the former to move the limb, the subject of the experiment has found it in a state of absolute paralysis. If the tongue be paralyzed in this manner, which we are told *is very easily done*, and a question then be put to the somnambulist, he will make violent efforts to speak, but to no purpose. His face will swell and become flushed with the ex-

ertion, and his features express the most painful efforts, yet not a word can be got out. Georget informs us, that he once made an experiment to ascertain whether the muscles of respiration situated about the chest, could be affected with magnetic paralysis,—when, to his great alarm, he perceived that the chest became entirely motionless, and the patient appeared to be in imminent danger of suffocation. If the patient be roused from his sleep by the magnetizer, without having his tongue, or his limbs, or his senses, previously *deparalyzed*, this palsy continues, and nothing, it is said, can exceed the surprise and fright experienced by the patient, when upon first waking he finds himself unable to speak, or to move his arms or his legs, or perhaps perfectly deaf.

When a limb or a muscle is subjected to the magnetic influence, the patient at first feels extreme coldness in the part, which is soon followed by prickling, and a feeling of weight and numbness. At length it becomes stiff, or rigid, and loses all power of motion and sensation. In a little while it becomes cold, and sometimes has the peculiar whiteness which the fingers exhibit after exposure to severe cold.

The state of the mental faculties in magnetic sleep remains to be noticed. In many respects the state of these faculties resembles their ordinary condition. Persons under the influence of animal magnetism exercise their powers of intelligence, like those who are awake. They think, talk, laugh, reason, &c. as they do in ordinary circumstances, though their senses are affected in the singular modes above described. But the state of their mental powers presents some remarkable peculiarities. A person in a magnetic sleep has a perfect recollection of all that has passed on all former occasions of the same kind; but he loses this recollection entirely as soon as he awakes, and recovers the whole of it when plunged into magnetic sleep again. He seems, indeed, to possess two existences, entirely separate from each other. When awakened, he forgets every thing which he had said or done, or that occurred to him, while in a state of somnambulism; but remembers the whole of it again whenever this state is renewed. Besides this remarkable double memory, the faculty of memory acquires a strength far beyond its ordinary power. Magnetic sleepers sometimes recite with the utmost correctness long pieces of poetry, which they had learned and forgotten, or which, perhaps, they had only read. Their internal perceptions acquire an acuteness and vividness, to which, at other times they are strangers. Persons of very ordinary capacity seem to acquire by the magnetic influence, a keenness of perception, a strength of judgment, and a vividness of imagination, which forms a striking contrast with their usual mediocrity of talent and temperament. One writer observes, that they appear to soar in a

more elevated region. Every thing is dignified and embellished by the power of their minds. They paint objects in the most brilliant colours, and they display a power of eloquence, and a richness of language, wholly disproportioned to their ordinary ability and habits of mind.

It is also extremely remarkable, that the will of the somnambulist seems to be entirely under the control of the magnetizer. It appears indeed to be nothing but an instrument in his hands, which he directs and uses at pleasure. The somnambulist acts only through him; his desires, his thoughts are influenced by him; even his muscles and limbs and senses become paralysed at the command of the magnetizer. The latter can extract from him his most secret thoughts, and compel him to disclose facts or circumstances within his knowledge, affecting his own character or interest, or those of others, and which he may have the strongest motives to keep inviolably secret. The magnetizer has the key of his cabinet, and can open it and examine its contents whenever he pleases. Notwithstanding the extreme improbability of many of these alleged facts relating to animal magnetism, there are several phenomena of ordinary somnambulism, and of certain nervous diseases, which indicate states of the nervous system, very similar to those which must be supposed to exist in magnetic somnambulists, if the statements on this subject be admitted to be true. Even ordinary sleep presents some phenomena very similar to those of magnetic sleep. In common sleep, there is a *universal* paralysis of sensation and muscular motion, frequently accompanied with an active state of the intellectual and moral powers. In magnetic sleep, there is a paralysis of sensation, with an active state both of the mental and of the muscular powers—and the same is the fact in common somnambulism. The power of distinct vision, where the eyes are shut and covered with bandages, appeared to be one of the most incredible fictions of the magnetizers, until the authentic narrative of Jane Rider proved to us, that the same astonishing phenomena may occur in common somnambulism. The power of hearing and of carrying on a conversation when plunged in sleep, is not peculiar to persons under the influence of animal magnetism; for common somnambulists sometimes do the same. Dupau relates the case of an officer, who, from his infancy, enjoyed the power of hearing and understanding what was said to him, while asleep, and of answering questions without waking up. One day, several of his friends having surprised him asleep in his chamber, began to converse with him, and received brief, but pertinent answers to their questions. One of them designedly used some insulting language to the officer, which the latter resented with great indignation, and the quarrel at last became so warm, that a chal-

lenge passed from the other party, and was accepted on the spot: a pistol being placed in the hand of the officer, he presented it and fired, and was waked by the report; and was astonished to find himself among a party of his friends, who were highly amused at the scene. This officer in his sleep retained his sense of hearing, and by this means, another person could converse with him, without his waking up; but it was necessary, as in some other cases of somnambulism, and as it is also sometimes in magnetic sleep, for the other party to *touch some part of his body*, in order to make him hear.*

The paralysis of the muscles, which we are informed may be produced by the magnetic influence, has a counterpart in some cases of imperfect sleep. The author has, in numerous instances fallen into a state of partial sleep, in which his consciousness was not suspended, nor his senses asleep, and yet no effort he could exert, would bring any of his muscles into action. The sense of helplessness was most distressing, and induced violent efforts to break the spell; but his limbs were fettered down immovably to the bed. Now if the whole muscular system may be reduced to a state of temporary paralysis, while the senses also, are in a state of repose, as in common sleep, or while the senses are awake, as in the state of imperfect sleep just mentioned, where is the extreme improbability, that a *part only of the muscular system* may be reduced to the same state of temporary paralysis, as is alleged to happen in some cases of magnetic sleep? The truth seems to be, that, as perfect sleep involves *all* the functions of animal life, imperfect sleep may affect *any part*, or for any thing we know to the contrary, *any one* of them. If in ordinary somnambulism, one of the senses may be awake, and even in a state of preternatural acuteness, while the others are wholly locked up from external impressions, how do we know, that some part of the muscular system may not be deprived of all power of action while all other parts of it retain this power in the fullest degree? So far as this, there appears to be nothing incredible, or even very improbable, in the accounts of the state of the system, when under the magnetic influence. But with regard to the transfer of the functions of one sense to the organs of another, the case is different, and derives no support from the analogy of common somnambulism, or imperfect sleep. The same is true of the pretended *clairvoyance* of magnetic sleepers.

It is worthy of remark, however, that the author of the narrative of Jane Rider, in order to account for the fact of her being able to see distinctly in the dark, with thick bandages over her eyes, is compelled to resort to a supposition, which is almost as difficult

* Lettres sur le Magnetisme Animale.

to admit as the transfer of the office of one sense to the organ of another. He observes, that for a person to see external objects, it is necessary that a *distinct* image of the object be formed on the retina, even though it be a *faint* one. Now he admits that the rays of light, in passing through a bandage, or through the eyelids, are so variously refracted that no distinct image can be formed. If this be so, it may be asked, how was it possible for Jane Rider to see *distinctly*, under such circumstances? To answer this question, the author resorts to a supposition, that a change takes place in the state of the brain, a certain excitement of the organ, in consequence of which, perception, so far at least as relates to this order of impressions, is affected more readily than usual. "In this way," says the author, "we can conceive that it would be possible for even a confused image to be perceived." This ingenious supposition of the author would be more admissible, if it were easy to conceive that any image could be formed by the light that could struggle through a thick wadding of cotton, enveloped in a black silk handkerchief, applied over the closed eyelids of a person in a dark room. In passing through such a thickness of substances, nearly opaque, the very few rays of light that might eventually work their way through, would undergo innumerable refractions before they reached the eye; so that it is not very easy to conceive in what manner any image at all could be formed; unless we suppose the eye to possess the power of restoring the dislocated rays to the directions in which they emanated from the objects, as well as of refracting them afterwards to foci, on its own retina.

The excitation of the intellectual powers, and the phenomena of double consciousness, are common to magnetic and ordinary somnambulism.

But one of the most incredible things in the accounts of the magnetizers is, that such extraordinary states of the system should be produced by means apparently so inadequate, as quietly stroking the body and limbs of the subject, or making a few unmeaning gesticulations, or merely exerting an act of the will. In respect to the last named means, in particular, it appears wholly inconceivable, that it could transmit any influence from the magnetizer to the other party, notwithstanding the ingenious theory of magnetism proposed by Rostan. We should not forget, however, that the human body, in certain states of the nervous system, is sensible to certain influences or emanations, which are wholly imperceptible to it under all other circumstances. Caspar Hauser, we are told, was extremely sensible to the influence of common magnetism, and to metallic emanations. On one occasion, Professor Daumer placed a gold ring, a steel and brass compass, and a silver drawing-pen under some

paper, so that it was impossible for him to see what was concealed under it. He was then directed to move his finger over the paper without touching it. He did so, and was able accurately to distinguish all these metallic substances from each other, according to their respective matter and form. When Daumer held the north pole of a magnet towards him, Caspar put his hand to the pit of his stomach, and said, that it produced *a drawing sensation*, and that a current of air seemed to proceed from him. The south pole affected him less, and he said that it *blew upon him*. He displayed this extraordinary sensibility to metallic influences on many other occasions. We are also told that animal emanations affected him in a manner equally surprising; and he called the streaming of the magnetic fluid upon him, a *blowing upon him*. These sensations he experienced, not only when in contact with men, but when they extended the ends of their fingers towards him, at some distance; and even when he touched the inferior animals. When he laid his hand upon a horse, he said that a cold sensation went up his arm. When he caught a cat by the tail, he was seized with a fit of shivering, as if he had received a blow upon his hand.

Before dismissing this subject, it may not be improper to notice the opinions of some distinguished men who have paid attention to it, and who will scarcely be suspected of any excess of credulity.

The committee of the medical section of the French Royal Academy of Sciences, it appears evident from their report on animal magnetism, were staggered by the extraordinary facts which they had witnessed; and were compelled to give a reluctant assent to the pretensions of the magnetizers; though they seem almost afraid of disclosing their convictions of the reality of this specious *thaumaturgy.*

"We do not (say they) demand of you a blind belief of all that we have reported. We conceive that a great proportion of these facts are of a nature so extraordinary, that you cannot accord them such credence. Perhaps we ourselves might have ventured to manifest a similar incredulity, if, changing characters, you had come to announce them to us; and we, like you, had neither seen nor observed, nor studied, nor followed any thing of the kind."

To this remarkable testimony of some of the most distinguished medical men in Paris, may be added the following, from two of the most illustrious characters of the age, Cuvier and Laplace, as cited by Rostan in the Dictionnaire de Médécine.

Cuvier remarks on this subject in the following manner: "It must be confessed, that it is very difficult in the experiments made in order to ascertain the natural influence of the nervous system

of wo different individuals upon each other, to distinguish the effect of the imagination of the person who is the subject of the experiment from the physical effect produced by the other. Yet the effects produced on persons already in a state of unconsciousness, before the experiment began, on others after the experiments themselves had produced a suspension of consciousness, and those which animals sometimes exhibit, scarcely permit us to doubt that the proximity of two living bodies, in certain positions, and with certain movements, is capable of producing a real effect, independent of all participation of the imagination of one of the two parties. It also clearly appears that these effects are owing to some kind of communication established between their two nervous systems."

The celebrated Laplace expresses himself on the same subject, in the following terms:

"The singular effects which result from the extreme sensibility of the nerves in certain individuals, have given birth to different opinions on the existence of a new agent, which has received the name of animal magnetism. It is natural to think that the action of these causes is very feeble, and may easily be disturbed by a great variety of accidental circumstances; so that from the fact that in many cases this agent has failed to manifest itself, we ought not to conclude that it never exists. We are so far from being acquainted with all the agents in nature, and their different modes of action, that it would be unphilosophical to deny the existence of phenomena, merely because in the present state of our knowledge they are inexplicable."

CHAPTER XXXIII.

DEATH.

Every organized living being is subject to death, *i. e.* a cessation of its living functions, and the return of the organized matter of which it is composed, to the jurisdiction of the physical laws of nature. Death has been defined "the irrevocable cessation of those functions which bestow on organized living beings the power of resisting* the destructive influences with which they are surrounded."

Death may happen at different periods of life, in different modes, and from various causes. A period is assigned by

* Lepelletier.

nature in every organized being, for the cessation of life; and whenever death happens in conformity with this law, it may be termed *natural*, or *senile* death. Every other kind of death may be called *accidental.*

Natural death is that which occurs when the vital mechanism has passed through all its periods; and it is the result of the gradual deterioration or wearing away of the organization by the operations of life, in consequence of which the organs and tissues gradually lose the predominance which they previously held over the physical and chemical forces of matter, maintain for a time a feeble contest with them, but at length become victims in the unequal struggle. The nature of the deteriorations of the organization, which lead to natural death, is unknown. Different physiologists have assigned different changes, as *e. g.* the ossification of the arteries producing an obstacle to the free distribution of blood, the ossification of the costal cartilages; the diminution of the capillary system of the lungs, causing an imperfect hematosis; a gradual shrivelling or atrophy, and induration of the nervous system, rendering it incapable of effecting its important function, viz. innervation. Adelon remarks, that as life consists in the reciprocal action of arterial blood, and of the nervous influence, it is natural to suppose, that in general, death, and particularly senile death, is owing to a cessation of one or the other of these two actions; and hence he supposes that gradual changes in the lungs, leading to an imperfect hematosis, and an atrophy and induration of the nervous system, gradually destroying the function of innervation, are two common causes of death. But these gradual changes in the lungs and the nervous system, are themselves the results of some ulterior causes; and in the present state of our knowledge, he considers it impossible to determine what these causes are.

It is remarkable, that though senile death is most conformable to the laws of nature, and one might naturally suppose would be the most usual kind of death; yet, in fact, very few individuals die of old age. An immense majority die prematurely of *accidental* deaths; some in the embryo state, vast numbers in infancy, and multitudes of others, before reaching the natural term of human life.

Accidental death. Every kind of death which happens to organized beings, before the period assigned by nature for their duration, may be termed *accidental.* Accidental death may be owing to numerous causes, viz. 1. Defect of vital excitation, and of the reparation of the organs from a privation of air and food. 2. Accidental injuries, as blows, wounds, &c. producing mechanically or chemically a disorganization of parts essential to life. 3. The application of certain substances, called *poisons,* which corrode or inflame the organs, or else, being absorbed

into the circulation, exert some destructive influence over the nervous power, and annihilate this fundamental condition of life. 4. Exposure to intense cold, and the consequent abstraction of the caloric, indispensable to maintain the actions of life. 5. Violent passions of the mind, or excessive pain, suddenly exhausting the sensibility or irritability of the organs essential to life, and occasioning sudden death. 6. Morbid changes, spontaneously produced, of organs indispensable to life; or, in other words, *disease.*

Accidental death may either occur suddenly, or be slow in its approaches. When it happens suddenly, it is owing to some destructive cause, which destroys the power of one of the three great organs most essential to life, viz. the brain, the heart, or the lungs.

The death of the brain is termed *apoplexy.* It is characterized by a suspension of consciousness, of sensation, and of voluntary motion, difficult and stertorous respiration, bloating of the face, and violent beating of the temporal and carotid arteries. It may be produced by different causes impeding the action of the brain, as; 1. *Mechanical,* including blows, concussion, compression of the brain from effused blood, serum, or pus, depressed bone, foreign substances, &c. 2. *Vital,* as for example, inflammation, or congestion, ramollisement, tubercles, &c. 3. *Moral,* as profound grief or disappointment, or other depressing passions. The death of the brain occasions universal death, by annihilating all those functions which are dependent on the cerebral energy, especially respiration, and, through this, the functions of the heart.

The death of the heart is termed *syncope.* In this kind of death, the circulation is arrested, and all the organs of the body simultaneously deprived of the presence and excitation of arterial blood, an essential condition of all vital reaction. Syncope may be occasioned by numerous causes, physical, vital, and moral, as wounds of the heart, compression from water in the pericardium, ossification of the cardiac valves, &c., hemorrhages, violent pain, certain impressions upon the organs of sense, especially the sight, and smell, &c., sudden emotions of terror, &c. The death of the heart produces instantaneous death of all the great functions.

The death of the lungs is termed *asphyxia.* It produces universal death, according to Bichat, by preventing hematosis, in consequence of which, unarterialized or venous blood is transmitted to all parts of the body, and among them, to the brain and the heart, which become paralysed or poisoned by the contact of the black blood; and innervation, and the functions of the heart, are both annihilated.

Asphyxia, like apoplexy and syncope, is owing to a variety of

causes; as for example, mechanical obstruction to the entrance of air into the lungs, as in drowning, choking, &c.; in dropsy of the chest, &c.; the absence of oxygen in the air respired, or the breathing of noxious gases; inflammation or congestion of the lungs, morbid affections of the par vagum, paralysis, or want of power of the external muscles of respiration, &c. Asphyxia is characterized by a feeling of anguish and suffocation, oppression, difficult respiration, violent efforts of the inspiratory muscles, &c. violet colour of the face, lips, nails, followed by stupor, insensibility, and at last, cessation of the action of the heart. In death by lightning, and by some of the narcotic and animal poisons, there seems to be a simultaneous annihilation of all the powers of life. Lightning, however, is supposed by Edwards to extinguish life, by destroying the nervous power, which, he conjectures, it effects by producing a sudden expansion of the matter of the brain and nerves.

The physiology of sudden, accidental death, is not difficult to comprehend; for we are sufficiently acquainted with the functions of the great organs concerned in it, and with their mutual relations and connexions, to understand in what manner the death of the brain, the heart, or the lungs, speedily occasions universal death. But with accidental death, which approaches slowly, and seizes upon its victims by degrees, the case is otherwise. In many cases, however, even in this kind of accidental death, it is easy to discover the series of phenomena which terminates in death, because they are found to fall under one of the three classes above mentioned. Disease may be gradually developed in the brain, the heart, or the lungs, and, after a longer or shorter time, render the organ incapable of performing its functions, and eventually, thus occasion accidental death by apoplexy, asphyxia, or syncope. Morbid growths in the brain, tubercles, or hepatization of the lungs, ossification of the cardiac valves, &c. may thus occasion death, by a gradual approach of one of the three conditions above mentioned.

But the manner in which death is occasioned by diseases attacking organs which are not essential to life, is not so obvious. It is not very easy to comprehend in what manner simple fever, inflammation of the peritoneum, suppuration of the liver, dysentery, and many other diseases which terminate in death, bring on the fatal event. In all cases of death, however, one of the three great organs essential to life, the brain, the heart, or the lungs, must be primarily or secondarily affected; and perhaps it will depend either on the difference of predispositions in these organs to become affected, or on the morbid sympathies developed between the suffering organ, and one or other of these three great pillars of the living system, which shall be the first to give way,

and thus to bring on universal death. In most cases, death commences either in the lungs or in the brain, and the patient expires after a distressing struggle for breath, perhaps in the full possession of his reason almost to the last gasp; or he gradually sinks into a state of stupor and insensibility, accompanied with laborious and disordered respiration, which gradually ends in death. Death by asphyxia, in acute or chronic diseases, perhaps is frequently owing to weakness and exhaustion, so much affecting the muscles of respiration and the power of expectoration, as to render the mechanical motions of respiration more and more difficult, and, at the same time, to suffer the secretions of the bronchial tubes to accumulate, and obstruct the air-passages, until, from both causes, respiration becomes impossible, and death takes place by asphyxia. In many cases, death appears to commence in the brain and in the lungs nearly at the same time. This is owing to the mutual influence which these two organs exert upon each other; for in asphyxia the unarterialized blood which is transmitted to the brain sometimes appears to paralyze the organ, producing stupor and insensibility, which of course become combined with the symptoms of the primitive affection, asphyxia; and when death commences in the brain, the cessation of the cerebral influence produces a suspension of the action of the external muscles of respiration, and probably of the innervation of the par vagum, so that symptoms of asphyxia become blended with those of apoplexy.

Death by syncope sometimes occurs in chronic diseases of various kinds inducing great debility. Hydrothorax and phthisis pulmonalis frequently terminate fatally by syncope, though, in these cases, the syncope is complicated with asphyxia.

After death has taken place in the great vital organs, it extends by degrees to all the secondary functions of life; which successively die, until death is established over the whole system. The voluntary muscles manifest the last efforts of their vitality, in spontaneously contracting after the death of the heart and the brain; the gravid uterus sometimes contracts with so much energy as to expel the fœtus; the bladder and the rectum expel their respective contents; and the capillary circulation, absorption, and even nutrition, and calorification, frequently retain their activity a considerable time after the death of the great functions.

The signs of death have been divided into the *deceptive*, the *probable*, and the *certain*.*

The *deceptive* are absence of all motion, paleness, coldness,

* Lepelletier.

absence of bronchial exhalation, fixedness of the eyes, dilatation of the pupils, lividness, softness of the limbs.

The *probable* are rigidity of the limbs, opacity and sinking of the cornea, partial gangrene. The only *certain* one is *putrefaction.*

The universal death of the functions is followed by the re-establishment of the physical and chemical laws of nature over the now inanimate mass; the elements of which, no longer forcibly held together by the vital powers, break up their association, and obeying their natural affinities, *pair off,* to mingle with the common mass of inanimate elements.

THE END.

ERRATA.

Page 27,	line 10,	after "duration" insert "in an organized body."
86,	23,	for "influences" read "agents."
147,	36,	for "are" read "is."
147,	37,	for "furnish" read "furnishes."
152,	45,	for "—as" read ". As."
156,	16,	for "feel" read "define."
157,	29,	for "on" read "to."
160,	18,	*dele* "causing or."
160,	41,	for "or avoid" read "possession of."
191,	4,	for "medical chirurgical" read "medico-chirurgical."
289,	28,	for "irritation" read "inanition."
301,	9,	insert "and" after "colour."
384,	10,	*dele* "and" after "modifications."
385,	5,	*dele* "itself" after "sensation."
424,	12,	for "those" read "their."

The marginal note at the bottom of page 180 should have been placed at the foot of page 178, referring to the sentence at the top of the page.